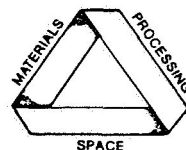
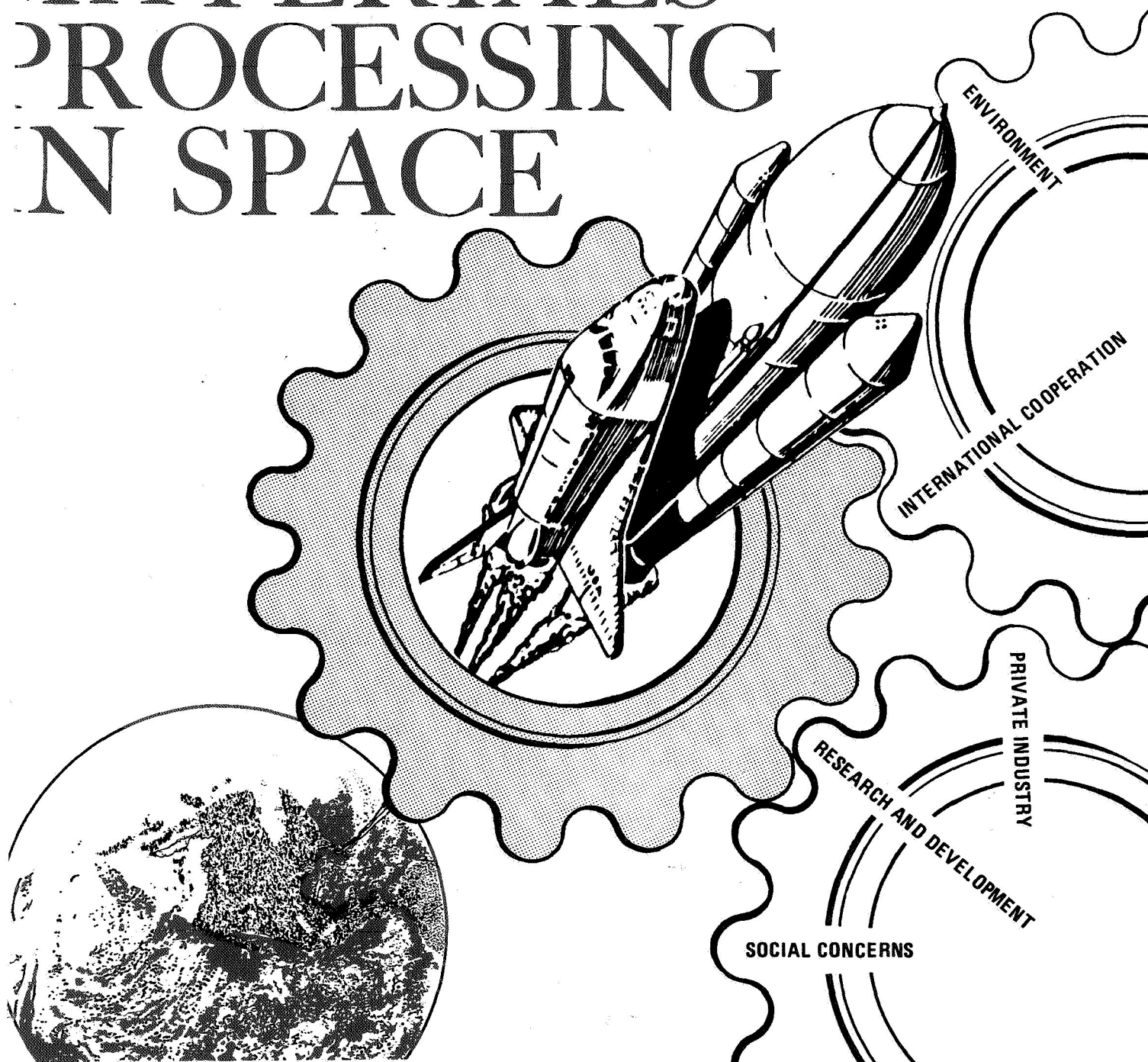


PLANNING FOR MATERIALS PROCESSING IN SPACE



N78-18090



FINAL REPORT
OF THE NASA/ASEE ENGINEERING SYSTEMS DESIGN
SUMMER FACULTY FELLOWSHIP PROGRAM CONDUCTED BY
THE COLLEGE OF ENGINEERING, THE UNIVERSITY OF ALABAMA,
UNDER NASA GRANT NGT 01-002-095.

PLANNING
FOR
MATERIALS PROCESSING
IN
SPACE

by the

UNIVERSITY OF ALABAMA
SUMMER FACULTY FELLOWS IN ENGINEERING SYSTEMS DESIGN
FINAL REPORT

Prepared Under Grant Number NGT 01-002-095

UNIVERSITY AFFAIRS OFFICE HEADQUARTERS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

with the cooperation of

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION
WASHINGTON, D.C.

and the

GEORGE C. MARSHALL SPACE FLIGHT CENTER
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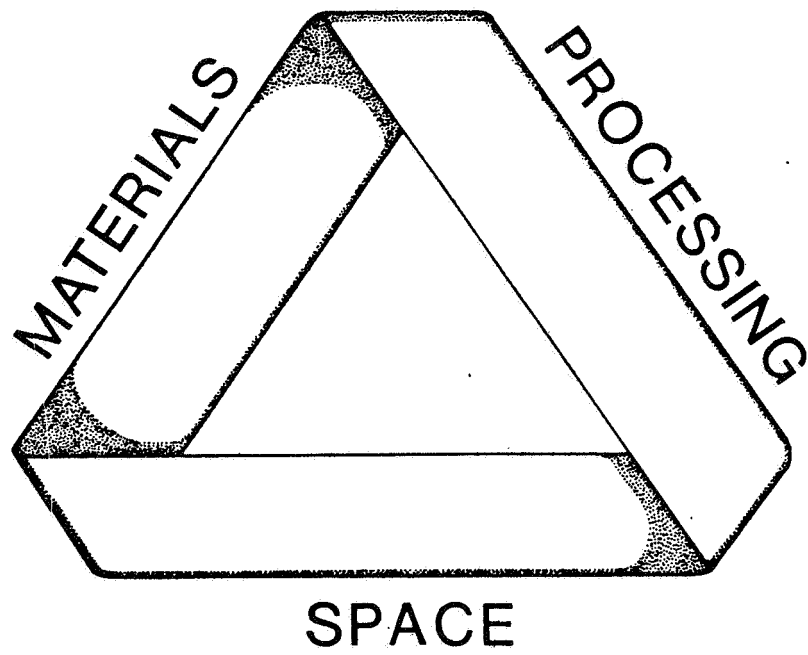


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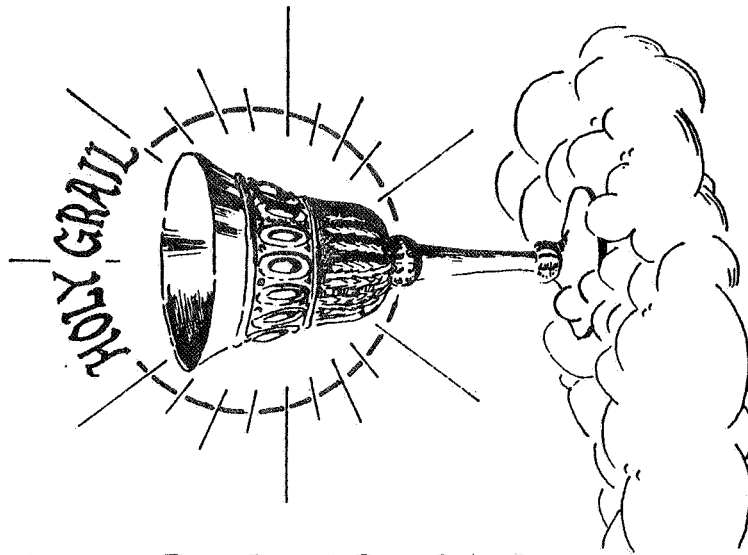


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ABSTRACT

PLANNING FOR
MATERIALS PROCESSING IN SPACE

A systems design study to describe the conceptual evolution, the institutional interrelationships and the basic physical requirements to implement materials processing in space was conducted. Planning for a "processing era" is emphasized in this report rather than the design of hardware.

A supporting ground-based R&D facility is recommended and described.

A concept for modular, unmanned orbiting facilities using the modified external tank of the Shuttle is presented. Organizational and funding structures which would provide for the efficient movement of materials from user to space and provide the incentive for industry participation are outlined. Contingency planning for perturbations of the system is included.

The use of advisory committees in two areas, planning for the preparation of a social impact assessment and an environmental impact statement, and identifying this program with a national goal are recommended to NASA as means of increasing public support for materials processing in space.

The Design Team of 19 participants concluded there would be a "processing era" before 2000. Eighteen specific recommendations are made to NASA to help implement that era.

ACKNOWLEDGEMENTS

The successful completion of the project would not have been achieved without the outstanding support of the many offices and personnel of the Marshall Space Flight Center as well as the many people from private industries, universities, the Federal Government, the European Space Agency, etc., who provided valuable resource material via seminars, telephone conversations, and written communications. It is not possible to give proper recognition to all of the individuals who participated in our program; however, we have listed certain speakers and others who contributed substantially to the effort. These contributors are listed in the front portion of this report and summaries of the speakers' remarks are given in Appendix L.

We wish to express our thanks to Dr. W. R. Lucas, Director of MSFC, Dr. George Bucher, Deputy Associate Director for Science, and Dr. Charles A. Lundquist, Director of Space Sciences Laboratory, for their guidance and advice during the study. Mr. Marion I. Kent, Assistant for University Relations and Dr. Mathias P. Siebel, our NASA Co-Director, deserve our special appreciation for their active role in pre-program planning as well as their support throughout the summer.

Excellent physical facilities were provided for us in Building 4723 (Training Branch). Many of the Training personnel helped us, but Mr. Clyde Hightower and Ms. Sharon Yates were especially helpful in a most cooperative and enthusiastic manner. Mr. John Hightower of Communications Skills, Inc., who is located in Building 4723, also is to be thanked for his kind assistance.

The success of any program depends on the resource material that is made available to the participants. The NASA Regional Information Center and the Redstone Scientific Information Center are run by dedicated, capable, and helpful librarians. These two centers have, over the years, provided excellent support to the NASA/ASEE programs and we sincerely appreciate the efforts of all of the professionals who assisted us; especially, Ms. Charlotte Dabbs of NASA and Mr. Jim Clark of RSIC.

Mr. Claude K. Brown and his staff of the MSFC Reproduction Branch gave us fine service on everything we turned in. The turn-around time on our first and second Interim Reports was amazingly short and contributed in no small way to the success of the summer study.

The Office of Public Affairs again ably assisted us throughout the program. Mr. Ed Schorsten, in particular, was an able and affable host on the MSFC tours. Excellent publicity was provided for our program.

Mssrs. George Wertz, Tommy Young, Bill Chandler and Ross Rives of Graphic Engineering, Hayes International, provided us with much needed support by providing the figures and art work that often were needed on a rush basis. Mr. Charles Allen of the Photo Lab provided similar support of our photographic needs. Without their cooperation, our final report and final presentation simply could not have been completed in a proper fashion.

The continued support and funding of these summer programs are due to Mr. Charles Carter of the Office of University Affairs at NASA Headquarters. Mr. Carter, along with Mr. Francis X. Bradley of ASEE Headquarters, and their many associates, certainly deserve recognition by the educational community for their sustained efforts in providing programs that are of great benefit to educators, NASA, and society in general.

The assistance of the many MSFC administrative assistants and secretaries is much appreciated. Ms. Eugenia Bledsoe, Program Secretary, along with Ms. Jan Lawson and Ms. Heidi Holmes, provided invaluable secretarial support throughout much of the summer. They did an outstanding job in typing the various reports and the visuals needed for the final presentation in an atmosphere of short deadlines and some tension.

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P R E F A C E

Systems engineering, or the systems approach, has become an accepted term to describe the multi-disciplinary character of the "systematic design" of any large system. The term seems to have originated in the aerospace field where the complexity of modern aerospace systems has demanded a systematically controlled design approach to insure that all factors of all subsystems, representing many disciplines, were carefully integrated into the final system.

The importance of the systems approach has been recognized by NASA to the extent that it has, in conjunction with the American Society for Engineering Education, sponsored six research oriented and four engineering systems design faculty fellowship programs at NASA centers in cooperations with local universities during this summer of 1977. Faculty fellowships were awarded to applicants selected from throughout the Nation. The Research Fellows were located in a laboratory where they conducted research on an individual basis and the Design Fellows participated as a group to learn the systems approach through a design problem. Centers and universities conducting design programs are:

- University of Alabama - Marshall Space Flight Center
- University of Houston and Rice University - Johnson Space Center
- Stanford University - Ames Research Center
- Old Dominion College - Langley Research Center

Dr. R. I. Vachon, Professor of Mechanical Engineering, Auburn University, initiated the Design Program at MSFC in the summer of 1967. Faculty collaboration between the University of Alabama and Auburn University continues; e.g., a set of notes (yet to be published) co-authored by Drs. Vachon and Lueg, entitled, "A Systems Approach to Getting Things Done," was given to each Fellow. These notes describe in some detail the methodology of the systems approach as it has evolved over the past eight Design Programs, and were of considerable help in teaching 1977 Fellows how to use the methodology.

Each of the four Design Programs uses a real-world situation to give the 20 or so faculty participants an opportunity to test the approach and live through and evaluate the group dynamics of the effort. The learning experience has an added advantage in that each center and NASA, through sharing the support of the programs, benefit from interaction with the faculty. The result of the program is an unbiased study and opinion on a topic of interest to NASA. Each participant then carries this experience to his home institution where either he may develop class projects that use a similar approach or he, with others, may select a project to involve faculty and students to solve a real problem using this approach.

The Alabama-MSFC participants were involved in a complete systems study with the objective to "design a system describing the conceptual evolution, the institutional interrelationships and the basic physical requirements to implement materials processing in space." Multidisciplinary design teams, with group leaders elected by the participants from their ranks, were established to achieve the design objective.

CHAPTER 1

INTRODUCTION

The theme for the 1977 Summer Faculty Fellowship Program in Engineering Systems Design was "Space Industrialization: A System, Feasibility and Economic Assessment of the Potential for Commercial Space Processing in the 1985 - 2000 Time Period." The project came about because of the interest of NASA officials at the Marshall Space Flight Center and some NASA contractors in the development of space as a natural resource. While some efforts at looking into the future have been made in the technological areas, long-range planning for the system as a whole has not yet developed. A feasibility study of space industrialization is a broad topic to consider. The MSFC-Alabama Design Team decided to confine its efforts to the subject of materials processing in space. The objective formulated for the study is, "Design a system describing the conceptual evolution, the institutional interrelationships and the basic physical requirements to implement materials processing in space."

Space presents the following special environmental properties to the materials technologist:

- ° Micro-gravity
- ° Hard vacuum with large pumping capacity
- ° Solar energy
- ° Large volume
- ° Low noise and potentially low vibration
- ° Large heat sink
- ° Near absence of atmosphere

Experiments on Skylab and the Apollo-Soyuz Test Project took advantage of some of these properties. The fact that 30 percent of the results were unexpected seems to, at least superficially, justify accelerated research and development activities in this area. Speculation by futurists with respect to the use of lunar and asteroidal materials [Gaffey - 77; Criswell - 75], as well as space energy facilities [Woodcock - 77] and space colonies [O'Neill - 74], has stimulated some firm thinking about materials processing. It seems

that now is an appropriate time to begin planning for the commercial use of space for materials processing.

Early in the design program, a rather extensive series of briefings by NASA personnel and contractors gave the participants a common base of knowledge concerning the NASA organization, its capability and its accomplishments. It soon became quite evident that while a number of products had been studied in detail, no product or process had been clearly identified which could become a prime candidate for processing in space. Several products or processes showed potential for economic development after considerable R&D effort, but the economic payback period appeared to be too long for industry to become interested.

The potential for commercial efforts to process materials in space justifies long-range planning for a "processing era." Significant social benefit may come from electronic or health-related products made possible by effectively using the space environment.

A number of feasibility studies on space industrialization have been conducted by outside contractors for NASA. Exhibit 1-1 is the result of an analysis of the summary reports of these contractors. The data developed and entered on this Exhibit are indicative of the direction these studies have taken. It appears that the technical aspects have been thoroughly addressed, but the factors of political feasibility, environmental impact, appropriate utilization of technology, societal goals and acceptance, and the legal aspects of using space have not been given the attention necessary for a thorough understanding and acceptance by the general public.

"Planning for Materials Processing in Space" is a study of a complex problem using a systems approach. Consensus views of the Design Team on the planning steps led to specific conclusions and recommendations which will help to implement the "processing era."

The Design Team made two assumptions: (1) A reusable earth-to-space transportation system will be available in the early 1980's and (2) the materials processing program within NASA will be small until R&D efforts bring about the "processing era."

The details of the systems approach used in this study are discussed in Chapter 2. The requirements to meet the design objective are identified in this chapter as: an organization plan, a funding plan, facilities, a ground-based R&D plan and consideration of some socio-political factors. The stage for the discussion of these requirements is set in Chapter 3 by reviewing the funding and hardware plans which NASA has made. The Shuttle Transportation System is reviewed in Chapter 4 along with a presentation of the Design Team's approach to an organization for the "processing era."

The funding problems associated with a program of materials processing in space are discussed in Chapter 5 while in Chapter 6 reviews are made of currently planned facilities such as Spacelab, current thinking about potential processes and products and a modular manufacturing facility using a modified external tank. A plan for a ground-based R&D effort to support the development of the space environment as a useful tool for materials processing is presented in Chapter 7. The many environmental, legal, labor and social concerns related to the design objective are discussed in Chapter 8.

Technologically, space industrialization and the associated activity of materials processing in space will produce direct benefits for our Nation and will transfer technology to the many diverse areas of human activity.

Dr. Robert A. Frosch, NASA Administrator, said recently, "Once we determine the Shuttle's capacity, I think we'll be doing things we don't even dream about today. We're just really beginning to get our imagination fired up about what we can do out there."

The primary thrust of this report is to encourage NASA and our Nation to proceed carefully, yet boldly, with "Planning for Materials Processing in Space."

Exhibit 1-1

SUMMARY OF SPACE INDUSTRIALIZATION STUDIES

TOPICS ADDRESSED IN REPORT	CONTRACTORS					
	1 ROCKWELL	2 GRUMMAN	3 McDAC	4 GE	5 AEROSPACE CORP.	6 SAI
OPPORTUNITIES FOR SPACE INDUSTRIALIZATION	3	2	1	3	3	3
SCHEDULING FOR SPACE INDUSTRIALIZATION	2	2	3	2	3	3
TECHNICAL FEASIBILITY	3	3	2	3	2	2
HARDWARE STUDIES	2	3	3	3	2	2
POLITICAL FEASIBILITY	1	1	1	1	2	1
ECONOMIC FEASIBILITY	2	3	3	2	1	3
ENVIRONMENTAL IMPACT	1	1	1	1	1	1
APPROPRIATE TECHNOLOGY	1	1	1	1	1	1
SOCIETAL GOALS	2	1	1	1	2	1
SOCIETAL ACCEPTANCE	1	1	1	1	1	1
SPACE LAW	1	1	1	1	1	1

LEGEND:**INDICATION OF EXTENT OF COVERAGE**

- 3 - HIGH
- 2 - MEDIUM
- 1 - LOW TO NONE

CONTRACTORS:

- 1. ROCKWELL INTERNATIONAL (ROCKWELL - 77)
- 2. GRUMMAN AEROSPACE CORP. (GRUMMAN - 77)
- 3. McDONNELL-DOUGLAS ASTRONAUTICS CO. (McDONNELL-DOUGLAS - 77)
- 4. GENERAL ELECTRIC CO. (GENERAL ELECTRIC - 73)
- 5. AEROSPACE CORP. (AEROSPACE - 76)
- 6. SCIENCE APPLICATIONS INC. (SCIENCE APPLICATIONS - 77)

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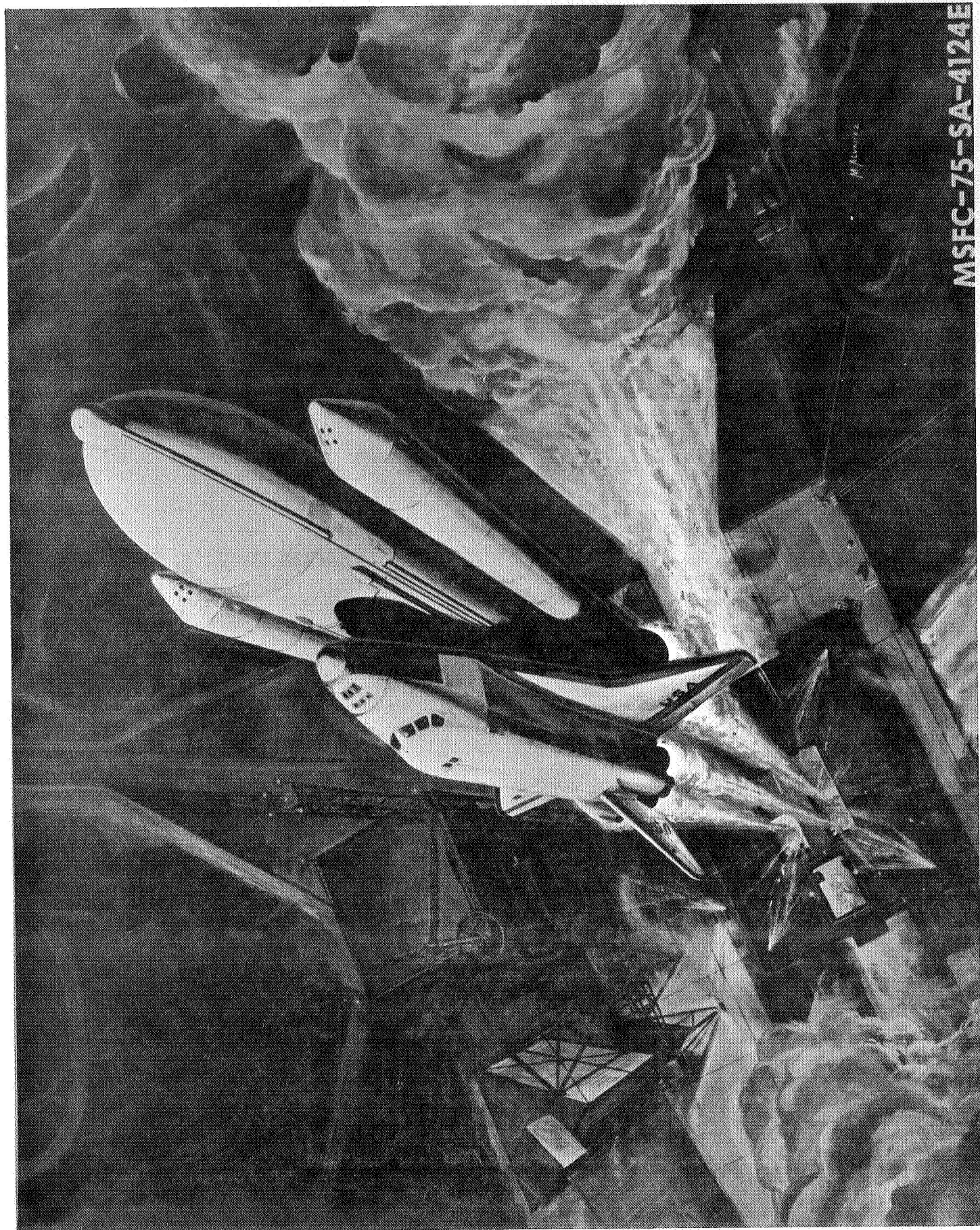
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MSFC-75-SA-4124E

CHAPTER 2

THE SYSTEMS APPROACH

The systems approach to problem solving as developed by Vachon and Lueg [Vachon - 77] was used throughout this study. The systems approach basically allows one to account for, in an orderly manner, the multiplicity of factors that affect a program. Further, the approach provides both an attack plan and a display of that attack.

The term, systems approach, which is more general than the term, systems engineering, describes a philosophy and view of the approach to the solution of complex, multidisciplinary problems. Definitions given to the systems approach are as many as the definitions of beauty, which exists in the eye of the beholder. Two definitions for consideration are:

- "The solution of a complete problem in its full environment by systematic assembly and matching of parts to solve the whole problem, in the context of the lifetime use of the system or plan, considering all aspects" [Frosch - 69], or

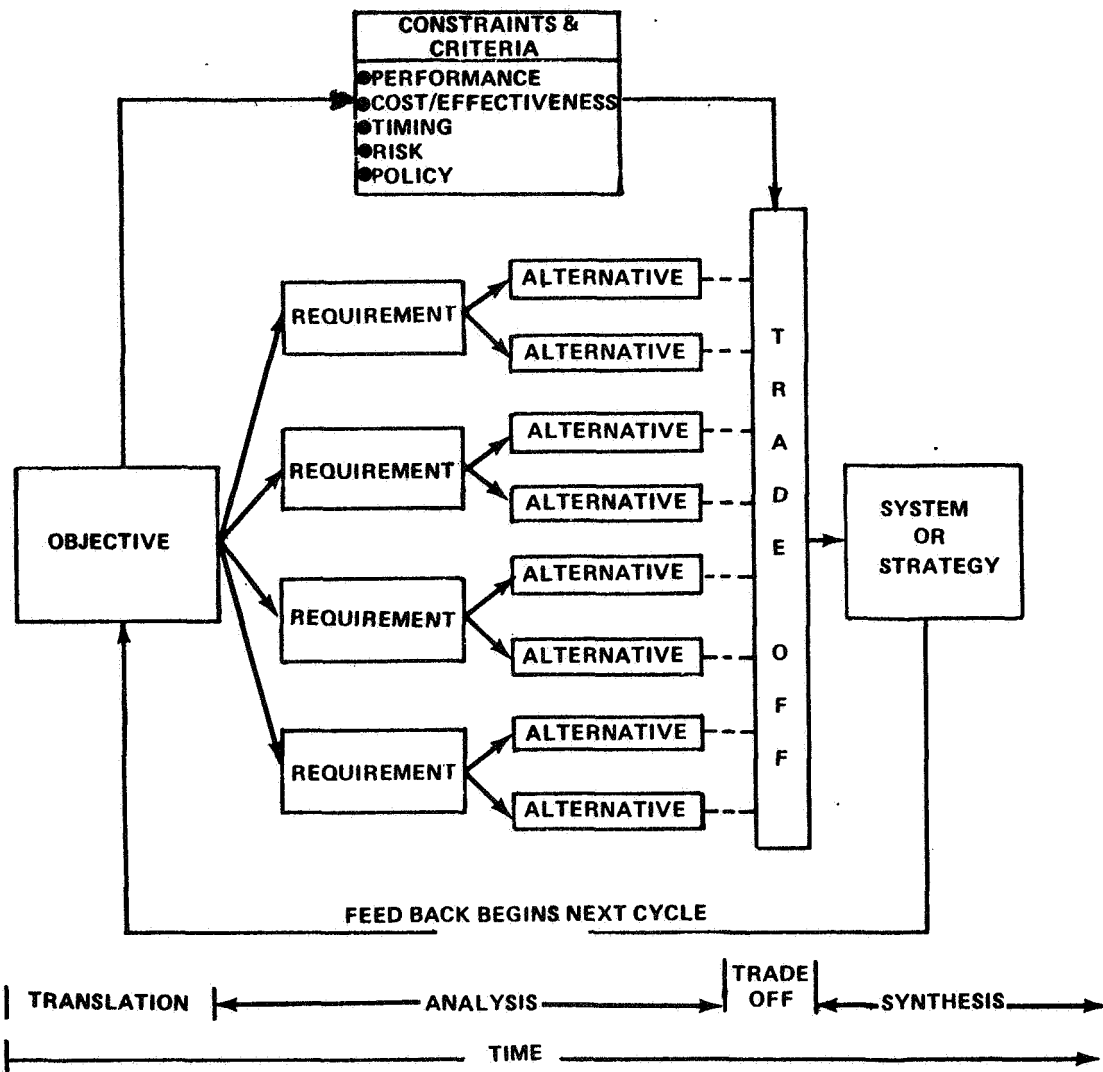
- An optimal solution or strategy to a complex multidisciplinary problem.

Exhibit 2-1 shows the steps involved in the systems approach and emphasizes its four phases: (1) translation, (2) analysis, (3) tradeoff, and (4) synthesis. These and other terms, called elements, are defined as follows:

- Translation -- determining a common language (or terminology) for the statement of the problem objective and the criteria and constraints that are acceptable to, and understandable by, all participants.
- Analysis -- determining as many alternative approaches as possible to solve the problem as a whole or to solve portions of the problem.
- Tradeoff Study -- applying selection criteria and constraints to choose the combination of alternatives to meet the objective.
- Synthesis -- a combination of the analysis and tradeoff phases to achieve a "best" solution to the problem statement that was structured during the translation phase.

Exhibit 2-1

A SYSTEMS APPROACH



- Objective -- the function that the system or strategy must perform or accomplish.
- Requirement -- a partial need (stated in most generic form) to satisfy the objective. A requirement may itself be an objective for a subsystem study.
- Alternative -- one of many ways to satisfy or implement a requirement.
- Controls -- those factors that regulate the system or strategy. Criteria and constraints are examples of controls.
- Criterion -- measure of the quality of the desired performance of the system or a strategy to meet an objective.
- Constraint -- an upper or lower limit or bound on the system or strategy. Constraints may be either fixed or variable.

As is indicated in Exhibit 2-1, the logic flow is from left to right. The selection of criteria and constraints (physical, fiscal, timing and policy) that are used to control the tradeoff of alternatives are either imposed by the political, physical and economic environment in which the system must operate or established by the system designer. It should also be understood that this process logic must be repeated in a cyclic manner as a system is developed from the initial concept to the final functioning system or strategy. The four phases -- Translation, Analysis, Tradeoff and Synthesis -- are carried out in each cycle; feedback exists between cycles as well as between phases within a cycle. Each succeeding cycle gives more detail to the developing strategy or solution. These diagrams do not indicate the necessity for involving many disciplines, nor do they indicate the necessity for attention to the group dynamics involved in progressing to a solution, strategy, or plan, whether it is tentative or a final system.

The practitioner of the systems approach methodology need not necessarily be a highly trained person but must exhibit common sense. An orderly approach and a logical manner of reasoning are desirable characteristics of the systems problem solver.

Some of the steps leading to a successful attack plan are specified below:

- State the objective.
- Identify the externally imposed controls (constraints and criteria). (The internally generated controls usually will not be apparent until the study is almost complete.)

- List the requirements needed to fulfill the objective; describe the requirements in generic terms to avoid missing items and to minimize the "shopping list".
- Gather information to determine the alternatives that satisfy the stated requirements. Each requirement can be used as a subsystem objective.
- List the constraints and criteria that are used in the subsystems studied and add to the overall set of controls.
- Compare the overall list of controls (externally imposed and internally generated) to the various alternatives and "trade-off" until a satisfactory solution to the stated objective is achieved.
- If no satisfactory solution results, feedback and iterate. Examine the original objective to see if it is stated realistically.

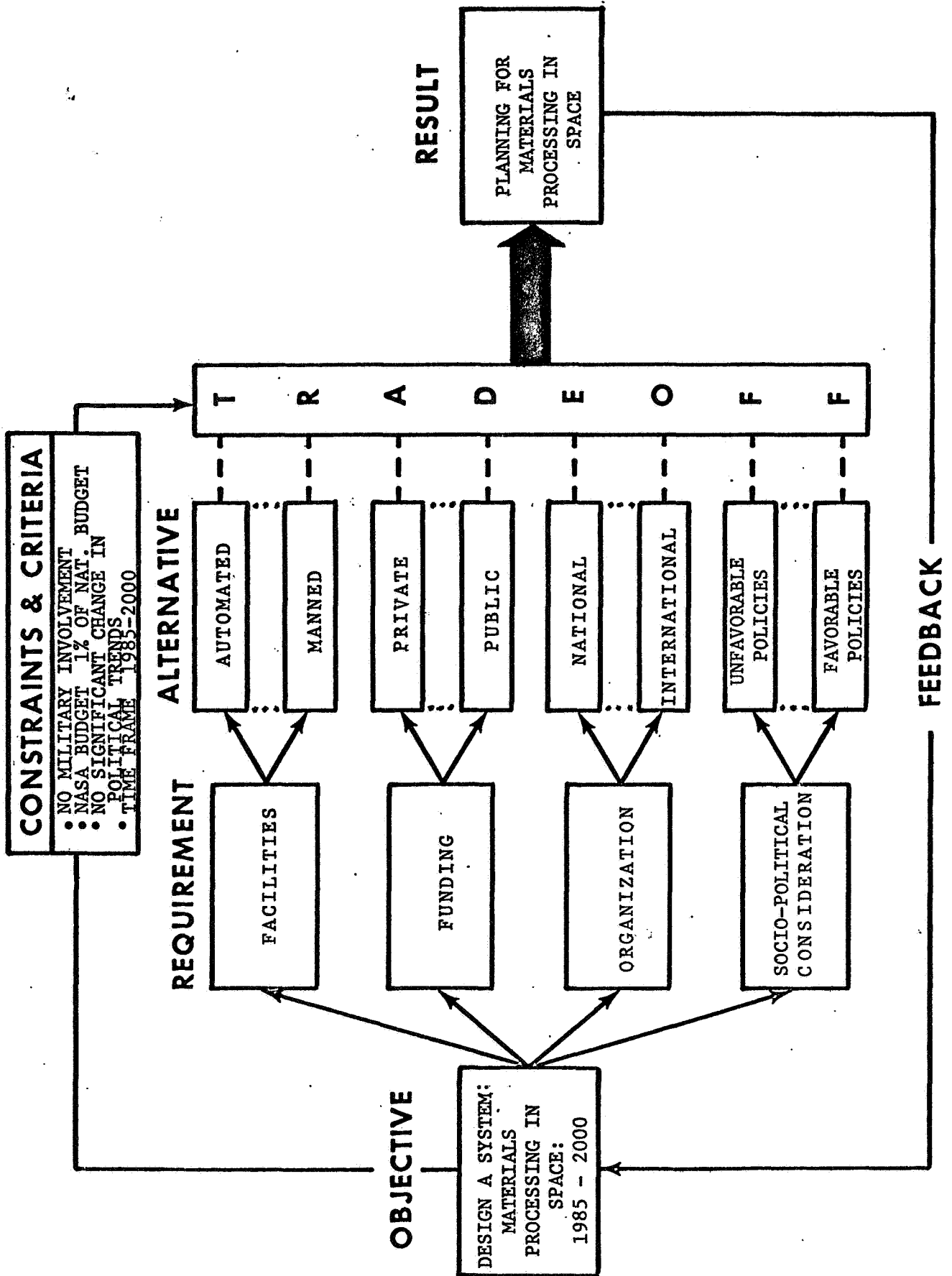
If one follows the above steps, it will typically stimulate further thought about constraints and criteria, additional requirements, etc. So the iterative process goes, hopefully leading to a "best" system or strategy. Exhibit 2-2 gives a broader view of this systems approach.

In this system design study, the iterative processes and more of the group dynamics that were involved can be seen in the study organization shown in Appendix K.

The systems diagram for this design study is shown in Exhibit 2-3. The abbreviated objective requirements and some representative controls are displayed. The complete list of controls follows:

- There will be a materials processing era in space.
- The present world population growth rate will not change.
- There will be no change in world quality of life aspirations.
- There will be no significant change in present world social-political trends.
- Materials processing efforts will be limited to the use of terrestrial materials only.
- Materials processing in space will involve minimal environmental degradation to the earth.
- A modest amount of materials, for processing in space, will be transported to orbit.

Exhibit 2-3



- Initially, materials processing will not be the prime mission of the Shuttle.
- A small number of people, 12 or less will be involved in an orbital facility for materials processing.
- Present NASA program awareness is taken as a minimum.
- No direct military applications are considered.
- The time frame for the study is 1985 - 2000.

During the course of the study, numerous alternatives were identified. These were traded-off in order to achieve a system which best "describes the conceptual evolution, the institutional interrelationships, and the physical requirements to implement materials processing in space."

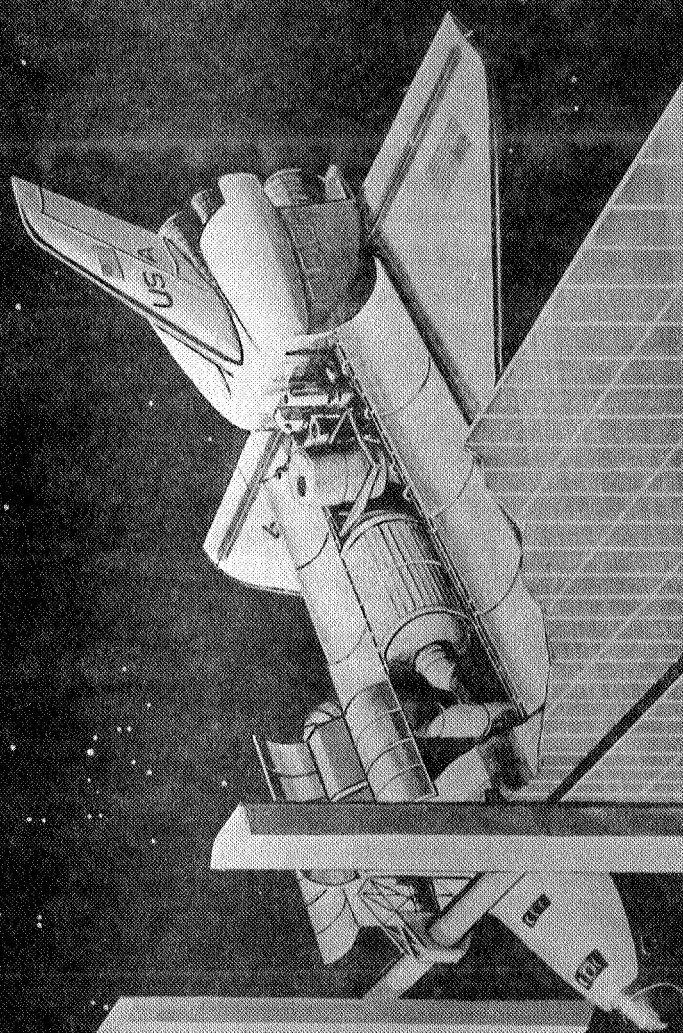
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POWER MODULE



MSFC-77-SP-4228A

CHAPTER 3

NASA PLANNING FOR MATERIALS PROCESSING IN SPACE

This chapter summarizes NASA planning as it is described in the current NASA five-year plan and in the internal NASA report, "Outlook for Space."

The NASA program on materials processing in space is intended to promote research on basic materials phenomena by providing opportunities for exceptional experiments in a unique environment. Prototype apparatus will be developed which will capitalize on the characterization of these phenomena and lead to a greater understanding of materials science. Ultimately, this will lead to space activities in materials science and technology funded by private and non-NASA government organizations.

Materials processing in space is expected to provide consequent increases in the general level of economic activity and improvements in the U. S. competitive position in the world market. This will be due to the development of high technology products requiring the application of space research data to processes on the ground. In addition, it is believed that active materials R&D in space can result in the invention of unique and highly valuable products that can only be made in space. This can lead to space manufacturing operations that earn direct profits.

NASA's role in the realization of these possibilities is to provide entry to space, develop the basic technology and techniques that all potential users will need to begin space activities and demonstrate the value of materials processing in space so as to provide a basis for investment decisions by others. Non-NASA government and industrial organizations are expected to eventually take over these activities as they develop into viable options.

Development of payloads for the earliest Shuttle missions will begin in FY78. These first payloads will be utilized for a step-by-step scientific approach to proof-of-principle experiments that can justify investment in space activity by private organizations. To the maximum extent possible, the experimental program will comprise investigations proposed in response to open solicitations and will be conducted by investigators drawn from the public and private organizations that make up the user community envisioned for materials processing in space. The technical content of the experiments on these early missions will be high-value applications

and will be balanced between biological and inorganic materials. Emphasis will be placed on preparation of human cell cultures and on the study of materials for electronic applications.

Continuity in this scientific R&D activity will be provided by a follow-on effort beginning in FY80 and emphasizing systematic research directed toward evolutionary enhancement of equipment capabilities. The major new capability contemplated for this phase of the program is the Molecular Shield Vacuum Facility, which will make space ultravacuum available for research purposes. The operational phase of this effort will emphasize a broadening involvement of prospective users and development of non-NASA participation through cooperative projects leading to follow-on efforts funded by private and public sources outside the Agency. Depending on the costs of space operations and the productivity of early experiments, non-NASA government and privately funded space processing activity is expected to develop during the period covered by this phase of the program. The activity is expected to begin with applied research at a relatively low level of effort and expand greatly when industry finds products that can be manufactured in space.

It is expected that by 1982 it will become appropriate to begin preparations to transfer experimental operations from Shuttle-Space-lab missions to a future space station. Research facilities for the space station will be designed to meet requirements based on the operational and technical results of the preceding experiment program. The scope of these facilities will be chosen to respond to the degree of user interest developed by that time. It is anticipated that the two primary design objectives for these facilities will be to minimize operational costs and provide sufficient capacity to support pilot-plant operations. The pilot plant operations will be used to produce products which have evolved out of the preceding R&D effort [NASA, Report - 76].

It is anticipated that the initial space station will be in low earth orbit and involve 4 to 6 people. It will consist of Shuttle-compatible station modules and manned continuously beginning 1985 - 1986. The initial space station would serve a number of purposes, including long duration research in various disciplines as well as commercial processing. Exhibit 3-1 includes a list of options. Exhibit 3-2 plots these options according to time and cost [NASA, Outlook - 76]. See Appendix A also.

The subsequent evolution of materials processing in space will depend on the experience gained in the initial space station. This evolution could take place along several paths, such as:

- Additional 4 to 6 man space stations, fully dedicated and optimized for commercial processing.
- The addition of commercial processing modules to the

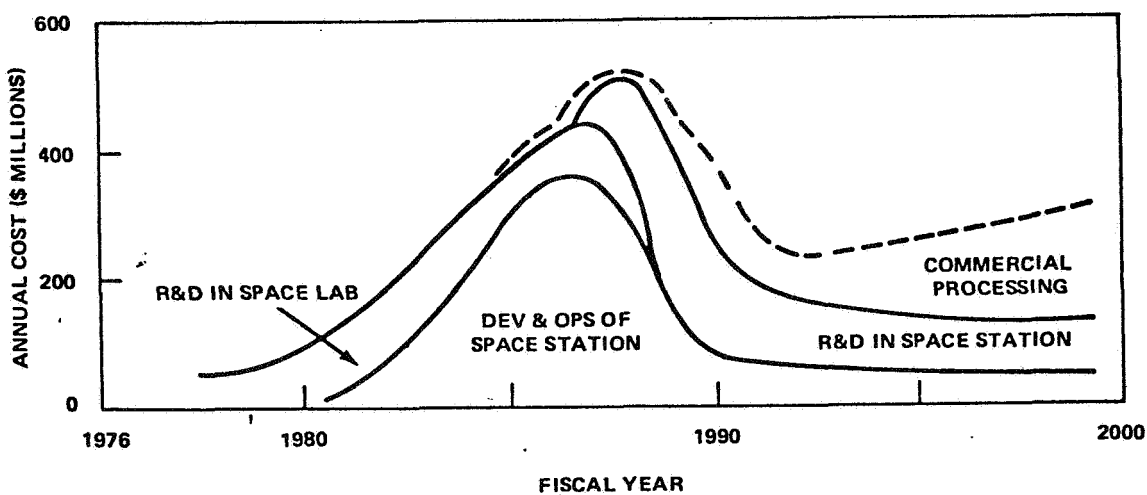
Exhibit 3-1

Earth Orbit Subprogram Options and Cost Estimates

OPTION	SYSTEMS REQUIRED	SYSTEMS COST	COST
A	"SHORT-DURATION" PHYSICAL CHEMICAL RESEARCH "SHORT-DURATION" LOW-G MATERIAL SCIENCE RESEARCH "SHORT-DURATION" BIOLOGICAL RESEARCH PRELIMINARY EFFECTS OF GRAVITY ON LIFE HUMAN PERFORMANCE IN SPACE - DEVELOPMENT PRELIMINARY DISEASE PROCESSES RESEARCH	\$ 160M 320 160 80 300 150	\$1170M
B	SPACE STATION 1A HUMAN PERFORMANCE IN SPACE - OPERATIONAL	\$1750M 590	\$3510M
C	"LONG-DURATION" PHYSICAL CHEMICAL RESEARCH "LONG-DURATION" LOW-G MATERIAL SCIENCE RESEARCH "LONG-DURATION" BIOLOGICAL RESEARCH	\$ 290M 590 290	\$4680M
D	COMMERCIAL PROCESSING	\$1000M	\$5680M
E	EFFECTS OF GRAVITY ON LIFE DISEASE PROCESSES RESEARCH	\$ 160M 310	\$6150M

Exhibit 3-2

Exploiting the Human Presence in Low-Earth Orbit Estimated Cost



initial space station.

- ° A continuously-operating large-scale materials processing facility in near-earth orbit.

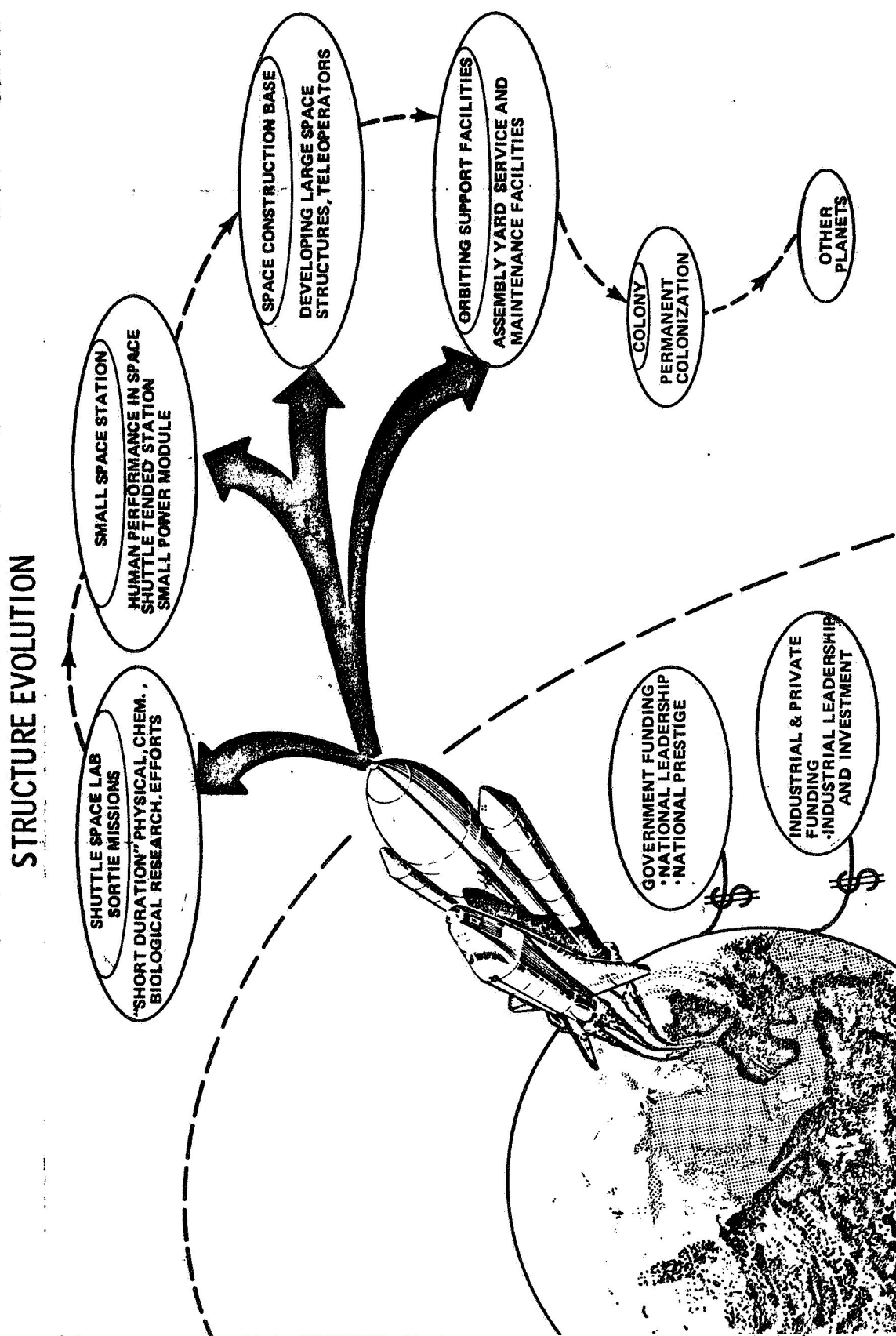
Long-range planning of any activity is tenuous at best. Long-range planning of materials processing in space will be profoundly influenced by scientific discoveries, by changes in international policy and national priorities and by technological progress.

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CHAPTER 4

ORGANIZATION

4.1 INTRODUCTION AND SUBSYSTEM DIAGRAM

This chapter discusses the organizational structure required to implement materials processing in space. The Shuttle Transportation System will be used for materials processing R&D efforts beginning in 1980. A review of the planned organization for using the Shuttle and the Spacelab is given in Section 4.2. This review will give the basis for projecting a future organization.

It is assumed that eventually a viable product will be found which requires one or more processing steps in space. This will usher in a "processing era" which will require an organizational structure beyond the R&D use of the Shuttle and Spacelab.

The organization subsystem for the "processing era" planning model is shown in Exhibit 4-1. Three separate areas of organization were identified as major requirements to satisfy the subsystem objective. The organization of the transportation system necessary to move materials from the user to the launch site and into orbit on a regular basis is presented in 4.3. The organization of the processing facility is discussed in 4.4. Finally, the organization of an orbital materials processing facility is discussed in 4.5.

4.2 PRESENT ORGANIZATION

4.2.1 INTRODUCTION

In order to make a leap into the future it is helpful to at least have a general idea of the present. This Section is a summary of the organization and operation of the current Space Transportation System (STS) as known to the Design Team. These facts were obtained from two sources [NASA, Civil - 77; NASA, Non-US - 77]. An attempt has been made to digest the information and restate it as a coherent whole. Limited time has prevented the inclusion of all useful information. For example, the Shuttle launch-oriented and cargo-oriented organizations are omitted.

The organization summary is divided into three parts shown in Exhibit 4.2. These are the Space Transportation Systems Directorate, ground support and the current pricing and scheduling policy. Ground support, discussed in Section 6.3 is more conjecture than fact; whereas, the discussion concerning the Space Transportation Systems Directorate and pricing and scheduling policy are based upon the previously mentioned references.

Exhibit 4-1

ORGANIZATION SUBSYSTEM CHART

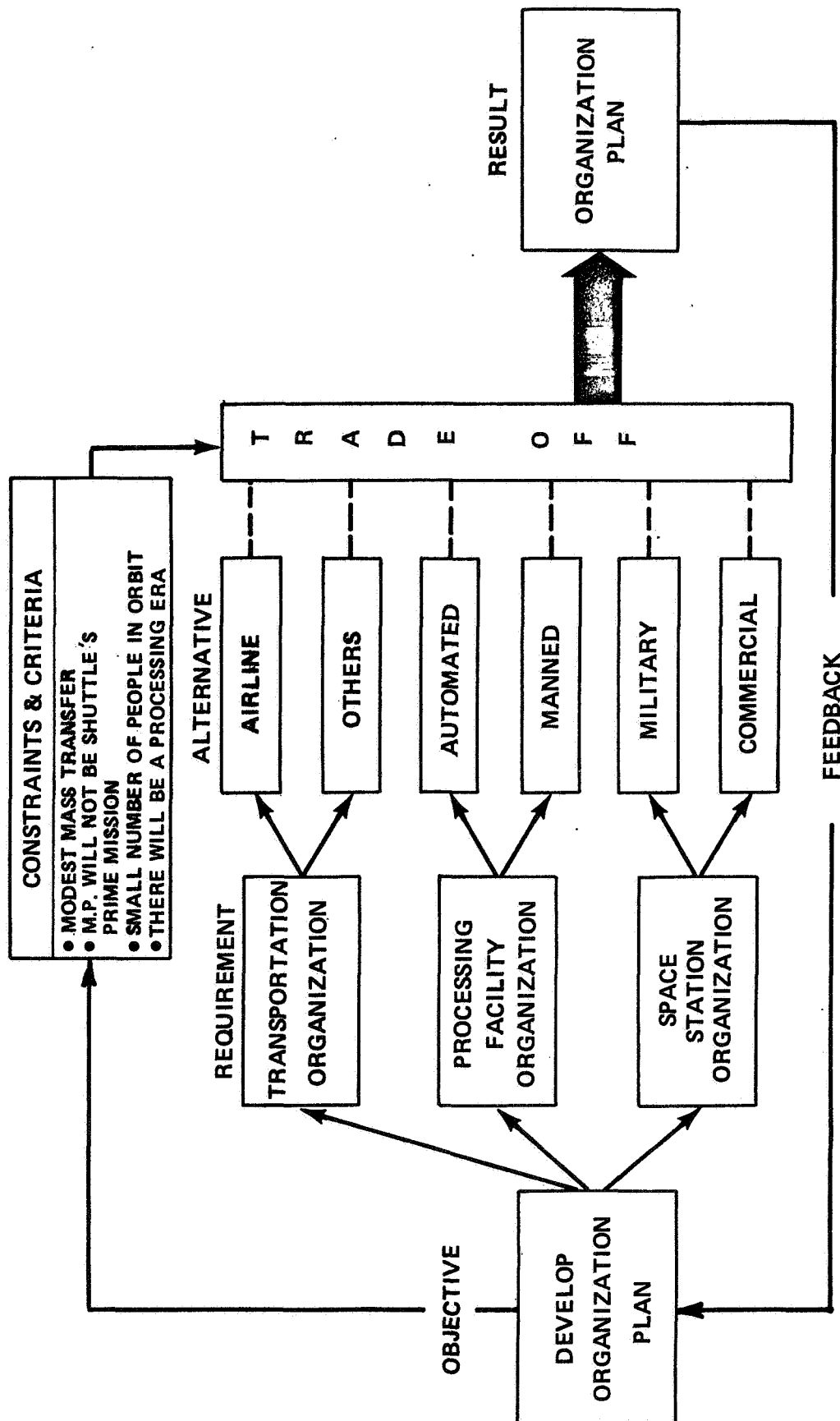
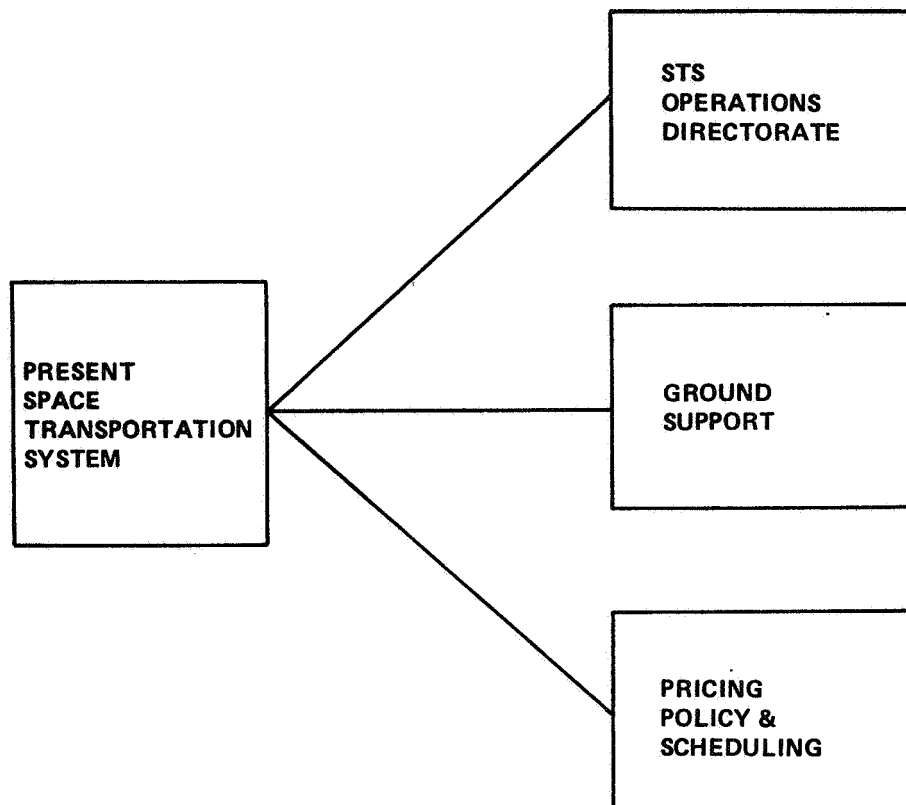


Exhibit 4-2

ELEMENTS OF THE PRESENT SPACE TRANSPORTATION SYSTEM



4.2.2 SPACE TRANSPORTATION SYSTEMS DIRECTORATE

The present structure which is being used to handle Shuttle operations is shown in Exhibit 4-3. An over-all Director of the Space Transportation Systems Operations is provided. The major activities of the office are divided into 6 groups. The 6 groupings are:

1. Safety
2. Pricing Launch Agreements and Customer Service Engineering
3. Systems Engineering and Logistics
4. Integrated Operations
5. Mission Analysis and Integration
6. Program Budget and Control

The Director's office provides over-all supervision and coordination.

1. Safety

This division oversees all operations to insure the health and safety of the Shuttle and its crew.

2. Pricing Launch Agreement and Customer Service Engineering

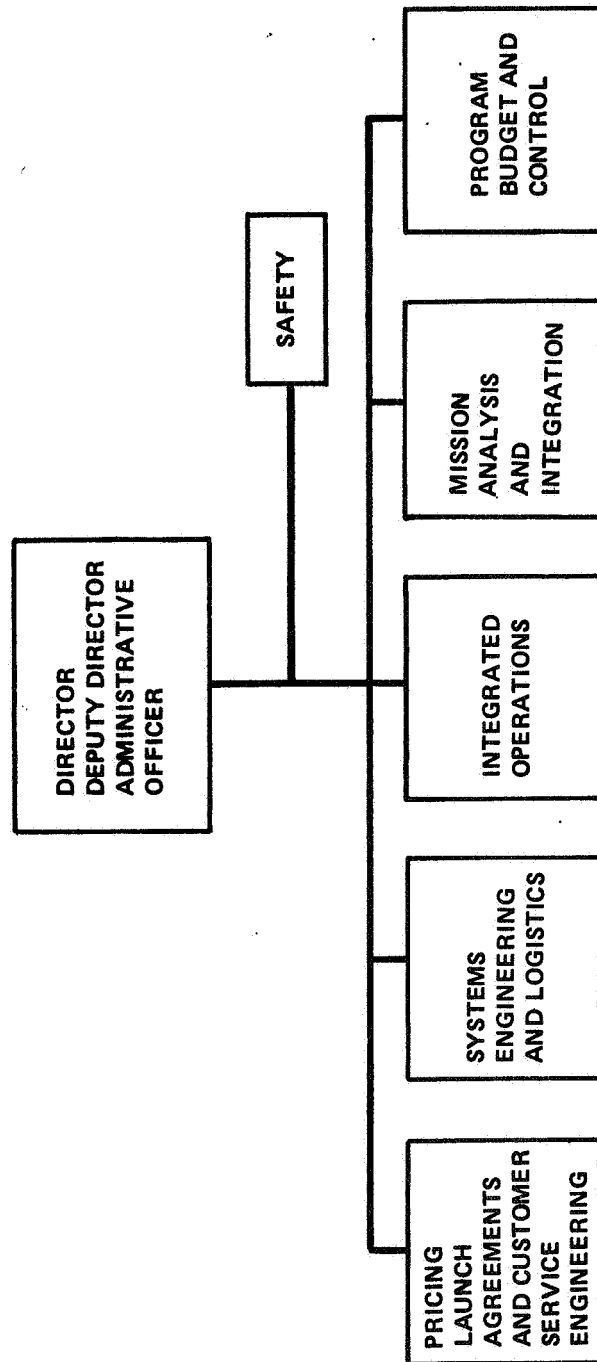
This division is responsible for the following tasks:

- ° Launch agreements
- ° Pricing policy
- ° Economic sensitivity analysis
- ° User handbook
- ° Precontract negotiations
- ° User charge analysis
- ° User services
- ° DoD agreements

This division is essentially the marketing arm of STS operations. The customer would initially deal with this division.

Exhibit 4-3

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF SPACE FLIGHT
SPACE TRANSPORTATION SYSTEMS (STS) OPERATIONS DIRECTORATE



3. Systems Engineering and Logistics

This division is responsible for the following tasks:

- Logistics (production, spares, maintenance and transportation)
- Configuration management
- Sustaining engineering
- Systems analysis
- Supplementary development

It may be seen from the tasks performed by this division that it is principally concerned with maintenance and spare parts of the Shuttle system itself. It is an internal division which in general does not interface with the customer.

4. Integrated Operations

This division is responsible for the following tasks:

- Operations plan
- Flight crew
- Network interface
- Data requirements and processing
- DoD mission support requirements
- Mission control center reconfiguration
- Launch processing
- Cargo handling and processing
- Launch and landing facilities
- Recovery requirements
- Range safety
- Western test range plans and requirements

The tasks listed show that this division is involved in operation planning, communications, cargo planning and launch integration. This division would handle cargo already contracted and assigned to a flight.

5. Mission Analysis and Integration

This division is responsible for the following tasks:

- STS traffic models
- Payload integration analysis
- Cargo manifesting
- Flight costs and assessments
- Flight assignments
- Orbital flight test integration
- Transition planning
- Mission assessment

Three factors which are critically important for Shuttle missions are weight, center-of-gravity and power. This division of the STS Directorate insures that the cargo requirements are configured to maximize usage of a Shuttle mission without exceeding the Shuttle's capacity; i.e., weight, center-of-gravity restriction and power.

6. Program Budget and Control

This division is responsible for the following tasks:

- Manpower analysis
- Program operating plan
- Financial management (fund authorization cost control, reimbursements)
- Program analysis (economic justification, tradeoff studies)
- Congressional interfaces
- General Accounting Office, Office of Management and Budget
- Program Control Management Information Center
- Schedule and reports

The major effort is financial planning and analysis. The division also provides the interface with Congress.

This is the division of tasks within the STS Operations Directorate. The customer need only deal with the STS Operations Directorate which is located in Washington, D.C.

4.2.3 GROUND SUPPORT FACILITIES

These facilities are discussed in Section 6.2.

4.2.4 PRICING AND SCHEDULING POLICY

The pricing and scheduling policy has been identified and is being implemented by the Pricing Launch Agreement and Customer Service Engineering Division of the Space Transportation Directorate. The policy has been published [NASA, Civil - 77; NASA, Non-US - 77]. This section will describe some of those policies.

The key elements which have been identified in the pricing and scheduling policy are:

- ° Contracts on a fixed-price basis
- ° Launch costs from FY80 - FY83 -- \$19.1M to \$20.1M
- ° Dedicated and shared flights
- ° After FY83 price is adjusted annually
- ° Standard and optional services
- ° Short-term call-ups, postponements, cancellations, standbys
- ° Exceptional and small self-contained payloads

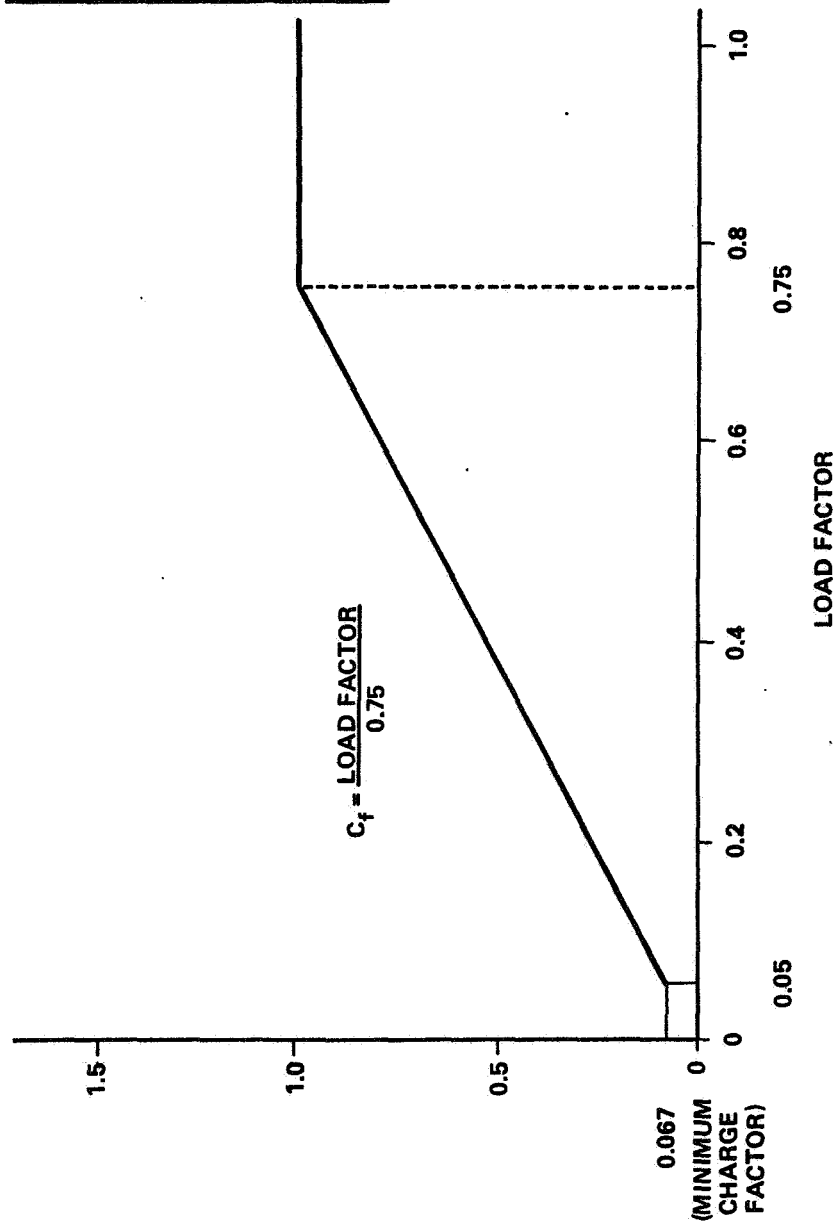
Each of the elements of the pricing and scheduling policy will be discussed below.

Customers contracting for the FY80 through FY83 will be guaranteed that no change in price will occur. The customer cost of a dedicated flight is obtained by adding the launch, refurbishment and a per flight depreciation cost. The cost of a single flight calculated in this fashion is between \$19.1M and \$20.1M. In the case of shared flights, costs will be pro-rated by either weight or length, using Exhibit 4-4. The larger load factor calculated using the equations in Exhibit 4-4 is used in computing the pro-rated cost. The fractional portion, C_F , of the total dedicated launch cost charged to the shared user is obtained from the graph shown on Exhibit 4-4. It may also be seen that different orbits have different prices for the same weight and length (see box on right of Exhibit 4-4). The pricing policy also includes a special price for exceptional and small self-contained payloads.

DETERMINATION OF CHARGE FACTOR (C_f) FOR I60 N. MI

$$\text{PRICE} = C_f \times \text{DEDICATED PRICE}$$

$$\text{LOAD FACTOR} = \left\{ \begin{array}{l} \frac{\text{PAYLOAD WEIGHT, LBS}}{\text{SHUTTLE CAPABILITY}} \\ \frac{\text{PAYLOAD LENGTH, FT}}{60} \end{array} \right\} \text{WHICHEVER IS GREATER}$$



SHUTTLE CAPABILITY	
INCLINATION IN DEGREES	WEIGHT IN THOUSANDS OF POUNDS
28.5	65
56	57
90	37
104	30

Payloads which have:

- ° High potential public benefit
- ° First-time R&D
- ° Approval by NASA Administrator

are considered exceptional. The price charged will be based on a dedicated launch cost of \$9.89 million. The reason is to encourage space technology research for public benefit.

Payloads which have the following characteristics:

- ° R&D payload
- ° Under 200 pounds and 5 cubic feet
- ° No services required

are considered small payloads. The price will be between \$3000 and \$10,000 and will depend on weight and size. They will be flown on a space available basis. If services are required, an additional fee may be charged.

Services which will be included in the \$19.1M to \$20.1M dedicated launch cost and hereafter referred to as standard services are:

- ° Payload design review
- ° Orbiter flight planning
- ° Payload safety review
- ° Payload installation verification and compatibility
- ° Three-man flight crew
- ° One day of on-orbit operations
- ° On-orbit payload handling
- ° Transmission of payload data
- ° Deployment of free flyer
- ° Standard mission destinations

- Altitude 160 N.Mi
- Inclination 28.5° or 56°

Those services which are not considered part of the dedicated flight cost and for which an extra fee will be charged are called optional services. The optional services are identified below:

- Payload mission planning
- Non-standard orbit flight and planning
- Launch window constraints
- Special integration and test
- Special crew training
- Upper stages and services
- Mission kits
- Spacelab, Long Duration Exposure Facility, special equipment
- Revisit and retrieval
- Extra-vehicular activity
- Additional time-on-orbit
- Payload data processing
- Western test range; 90° or 104° inclination standard mission available

A payment schedule has been determined and published in the NASA Management Instructions [NASA, Civil - 77; NASA, Non-US - 77]. The payment schedule calls for total payment before the launch. The schedule calls for percentages of the total user cost to be paid at fixed times starting 36 months before launch. There are alternative payment schedules which are available for users desiring a launch with a lead time shorter than 36 months. These accelerated payment schedules call for an additional fee.

The last key element in the pricing and scheduling policy to be discussed is the policy concerning short-term call-ups, postponements, cancellations and standbys.

A standby payload discount has been adopted in an attempt to keep the flights as full as possible and to accommodate those whose time restrictions are not tight. The discount applies to shared flight users only, and the flight will occur sometime during a negotiated one-year interval. The discount is 20 percent.

The possibility of postponements is considered by distinguishing three types of postponements:

1. Minor delays (up to three days)
2. More than one year before launch
3. One year or less before launch

Minor delays will incur no extra fee. The second category incurs no fee for one postponement. A fee of 5 percent of the user's flight cost will be assessed for any postponement after the first. A 5 percent fee plus an occupancy fee will be assessed for postponements in the third category shown above.

A cancellation fee will be charged to the user ranging from 10 percent to the full user fee depending on when the cancellation occurs.

Users requiring a flight in a shorter time than the standard three-year lead time will be charged a user short-term call-up fee. The three-year period is divided into two parts:

1. Less than three months
2. More than three months

Different short-term call-up fees are charged in each case.

A distinction must be made between shared and dedicated flights. The various categories are assessed in different ways, the details are in the NASA Management Instructions [NASA, Civil - 77; NASA, Non-US - 77].

More information concerning the Space Transportation System may be obtained by contacting

Mr. Chester M. Lee
 Director, STS Operations (Code M0)
 National Aeronautics and Space Administration
 Washington, D.C. 20546
 (202) 755-2347

In the several sections above:

- ° STS Operations Directorate
- ° Ground Support
- ° Pricing Policy and Scheduling

an attempt has been made to portray the planned operation of the

Space Transportation System as perceived by the Design Team. The present organization is not the last word. The structure is designed to handle customers flying cargo on a one-shot basis rather than a steady-state basis. Once the vehicle has been flying for some period of time, a new organizational structure will emerge to deal with a steady-state flow of similar types of cargo to and from orbit.

4.3 ORGANIZATION OF THE USER/PROCESSOR TRANSPORTATION SYSTEM

4.3.1 INTRODUCTION

The subsystem diagram for the User/Processor Transportation System is shown in Exhibit 4-5. The objective is to design a transportation organization subject to the constraints and criteria shown. Requirements for the subsystem have been identified. Various alternatives which may satisfy these requirements are also shown. The result was determined by considering the alternatives which would meet the objective subject to the constraints and criteria. The considerations involved in making the tradeoffs are discussed below.

4.3.2 GROUND TRANSPORTATION TO LAUNCH FACILITY

In the early R&D operations for materials processing the system is designed to integrate various sizes and weights over a long time period. In the beginning of the "processing era", a steady-state flow of material payloads will develop. More information about weight and size of the materials packages will be known. Then it will be desirable to arrange transportation to the launch site and integrate the payloads at the same time. Exhibit 4-5 shows three alternatives for transportation to the launch site. The airlines appeared to have the expertise and structure to handle the space-bound cargo. This can be done by using the airlines as commissioned agents to handle space cargo.

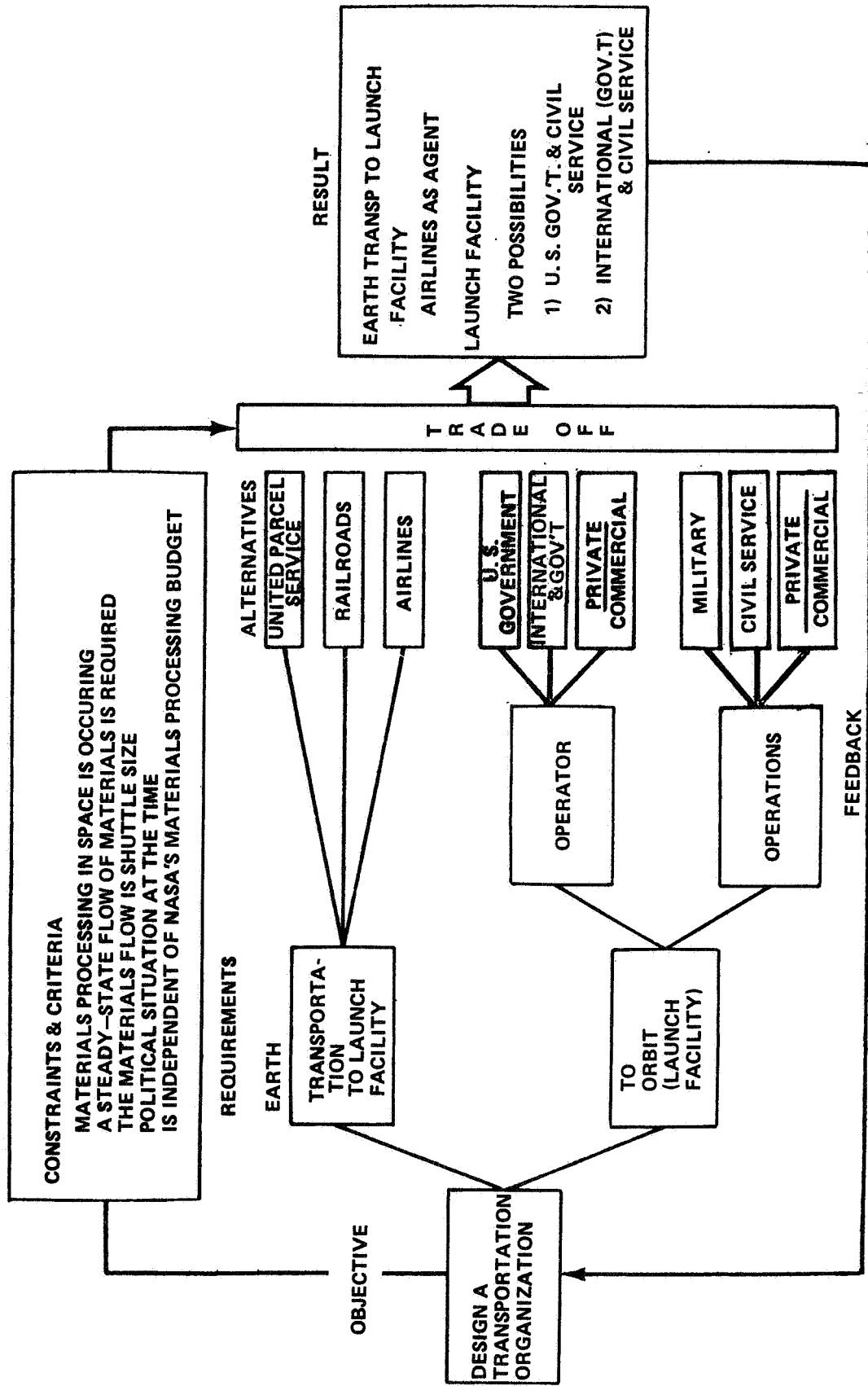
A computer program should be developed to handle the integration problem. This program would assign reservations on one of four flights leaving in any one month. Final flight determination would come when the computer program finds an arrangement of cargo within the vehicle's operations envelope.

The airlines could be commissioned as agents under three possible arrangements. First, the airlines could charge a reasonable fee for services rendered. Second, the exclusive right to carry the space cargo may be incentive enough for the airline to act as an agent. Third, the STS Operations Directorate may charge a franchise fee for an airline to function as an agent.

It is conceivable that packages could come from anywhere in the country. If this is so, it would be desirable to designate certain airports as concentration points. Cargo would be concentrated at

Exhibit 4-5

TRANSPORTATION ORGANIZATION SUBSYSTEM DIAGRAM



these points. Flights to the Kennedy Launch Center would then have a higher payload factor. Presumably this would be less expensive than flying any package directly to the launch site. The concentration points would be operated by a single airline or a consortium. The flights to the launch site may be assigned on a rotating basis among the members of the consortium or by the operator airline. It is strongly suggested that scheduled freight service to the launch site not occur until justified by tonnage requirements. In addition to the above, if a space user desires to fly direct, they should be allowed to contract with any of the agent airlines to do that.

There seems to be no need to set up a completely new system of space transportation agents throughout the country until existing systems (e.g., airlines) have been examined to see if they can or will handle the new business.

The Operations Directorate must budget funds to employ salesmen who will lecture, travel and sell the transportation system. They must be familiar with all the details of designing, integrating and flying a package that a customer may need to know. A WATS service should be provided so that customers may call directly and have questions answered. An on-line computer should be provided so that any customer with a "standard terminal" may call and obtain technical information concerning costs, schedules, services, etc. The program should be written so that an engineer representing a customer may obtain the needed information.

4.3.3 INTEGRATION

A computer code must be developed which can provide flight assignments quickly and efficiently. As a minimum, it should be designed to allocate payload among four flights and arrive at a flight assignment on one of four consecutive flights within one month's time. A user would be guaranteed a flight within this one-month time period. The computer code would arrive at cargo manifests within the vehicle envelope by allocating four full Shuttle cargoes among four Shuttle flights.

Assignment on a more definite basis, that is on a specified flight, could be made for a fee. The fee would be a penalty and be based on the cargo not flown or deadweight which is flown to satisfy center-of-gravity or power requirements. A maximum fee would be stated. This fee would be reduced to zero if other cargo is obtained to reduce the losses to the Space Transportation Systems Directorate.

4.3.4 GROUND TO SPACE

There are several options for organizing the ground to space organization. The operator may be any of the following:

- ° National Government

- International Government
- Private
- Combination

The specific choice of operator will also lead to a choice among the forms of operation. The possible forms of operation are:

- Military
- Semi-Military (e.g., police)
- Private Commercial
- Civil Service
- Combination (e.g., Post Office)

There are, therefore, two levels of choice. Once the operator has been determined, the possible form of operation will be constrained. Some of the choices are not very likely (e.g., military). At this time, the most likely possibilities are:

- National Government (U. S.)
Civil Service
- International Organization (Consortium)
Civil Service
- Combination
Private Commercial Organizational Structure
Civil Service

The future choice among these options will be determined by the political and economic strength of the U. S. and by the international situation.

4.4 ORGANIZATION OF THE PROCESSING FACILITY

In evaluating alternative schemes of organizing a space manufacturing facility, a number of factors must be considered. Of prime importance is ownership and the related problems of maintenance, safety and taxes. Unless the facility is completely self-contained there will be questions of how the day-by-day operation should be handled, and if it is manned, then a host of personnel organizational factors must also be considered.

It is becoming more and more apparent that a significant amount of government intervention and subsidy will be necessary to initiate commercial space ventures on the scale required for economically

profitable manufacturing. Under this constraint there are several alternatives. The government could own the entire facility and use its own personnel to perform experiments or to do processing for commercial users on contract. Such an arrangement has the serious drawback of requiring the divulgence of proprietary information, which most industries are not willing to do. A second possibility is for the government to provide a central support facility and then to turn over modular processing units to private users, either by leasing or through a buy-back arrangement. The user could then equip or modify the module at a secure location, with government interference only to insure safety. This approach is similar to that of the Spacelab facility, and should work satisfactorily for development and pilot plan operations. Maintenance and repair arrangements could be handled by contract, with the modules being readily transported on the Shuttle. As space manufacturing develops into larger operations, it will become feasible for larger industries and foreign countries to own entire free-flying manufacturing plants. In this case the organization would probably follow closely the owner's own internal organization and command structure with a minimum of government interaction except for transportation and emergencies.

Day-by-day operation can be classified into two categories, namely, manned or fully automated. If the manufacturing facility is fully automated, it must be organized around a central control computer that can be monitored, interrupted and reprogrammed from Earth. Monitoring of the processing would be done via a telemetry link and relay satellites. In this case, there are organizational considerations related to ownership or renting of the communication equipment, security and coding of messages, reliability of the communication system and the computer, and processing and storage of transmitted data. Precedents for much of the communication organization have been set by existing communication satellite systems. Commercial satellite tariffs are available and could be extended to messages originating in low-earth orbits. Also, several large corporations have their own in-house satellite communication systems that could easily be modified for space processing applications. The question of security can be handled by well-established coding techniques, and electronics reliability is expected to continue to improve in the future.

Organization of a manned facility in space presents a considerably more complicated set of problems. All of the automated facility organizational considerations above are still valid, but are somewhat less critical since there is now a manual backup of much of the automation. However, the organization must now consider the entire problem of life support. This includes physical, environmental and psychological factors. Before placing an operator on an orbiting facility, he must be specially trained in both routine manual skills and in the operation of the manufacturing of equipment. Few companies have the potential for such training, so arrangements to use

government facilities and instructors must be worked out. Personnel transportation on the Shuttle should prove a minor problem since this capability is incorporated in the design. However, such factors as the safety, morale, responsibilities and rescue provisions of the operator are very crucial and will have to be resolved with little or no precedent. For example, the question of rescue in space would involve not only the U. S. Government, but also any foreign countries that could lend assistance, and the organization considerations would be dependent on international treaties and other laws. One possible approach to resolving the personnel-related problems is to create a government agency along the lines of the Occupational Safety and Health Agency (OSHA) to set and enforce safety standards and to perhaps coordinate rescue efforts. Another approach is to provide a government-operated central core facility for space manufacturing units and therein provide life support facilities for a larger number of operators representing several different industrial concerns.

In evaluating the above alternatives the primary consideration will be to make the space manufacturing facility as attractive as possible to commercial investment. In this regard two considerations are crucial. First, the cost of using the facility must be kept to a minimum and, second, proprietary interests must be protected. This suggests a government-owned central support facility that would supply common services; e.g., communications, to a group of privately-owned processing modules. The private modules could be delivered unopened by the Shuttle to the support facility, and contract arrangements could be drawn up to cover the cost of transportation, power communications, remote control, the training and services of human operators, and other similar requirements. Proprietary agreements would also be feasible, since the modules would be wholly owned by the user. Of course, government-owned modules could also be provided on a lease basis for research work, habitability and small-scale manufacturers. Complete provisions for automation would be preferable so long as the processes are not excessively complex, but provision for human operators and technicians will be desirable in selected cases. The training of such personnel in space techniques, as opposed to technical manufacturing functions, should be done by the government since the necessary expertise and facilities will be readily available. Shuttle personnel should also be made available for services like extra-vehicular activity and emergency shut-down of the plant. Finally, rescue operations should certainly be coordinated by the government under international law and Earth-based rescue teams should be available at all times.

4.5 ORGANIZATION OF AN ORBITAL MATERIALS PROCESSING FACILITY

"An organization develops its broad objectives first and then creates the organizational and technological systems and subsystems to achieve its general objective and more specific goals" [Johnson - 76]. The development of objectives and the design of organizations

to achieve objectives, however, is not a linear process; existing organizational designs tend to bias the design of new organizations so that new organizations are often reproductions of existing models. The reason for this is that organizations are an extension of the society in which they exist and the selection of organizational goals derives from social processes. Therefore, socially acceptable goals for organizations generally mean socially and politically acceptable organizational designs.

The required elements of an orbital facility system does not change although the design of the organization may vary. The required elements of an orbital facility system are users, ground-based operations, communications and orbital facility operations. This is shown in Exhibit 4-6. The elements are the same if one proposes either manned or unmanned operations of the orbital facility.

The decision to use an unmanned, as opposed to a manned, orbital facility requires different organizational design; such as a greater emphasis on telecommunications for remote control of processing. The design problems, however, are similar in both manned and unmanned orbital facility systems. Many of the difficult organizational design problems are problems of human behavior, as the Hawthorne studies showed. In addition, the development of an orbital materials processing facility involves political decisions that directly impinge on organizational design.

In order to facilitate further discussion of the problems of this organizational design, the terms used to describe the requirements for the orbital facility system are defined:

User -- Those who need the unique environment provided by the orbital facility and are permitted access to it.

Ground-Based Operations -- The organization and administration of the ground-based support system that promotes user demand, facilitates user access and controls the primary communication links to the orbital facility.

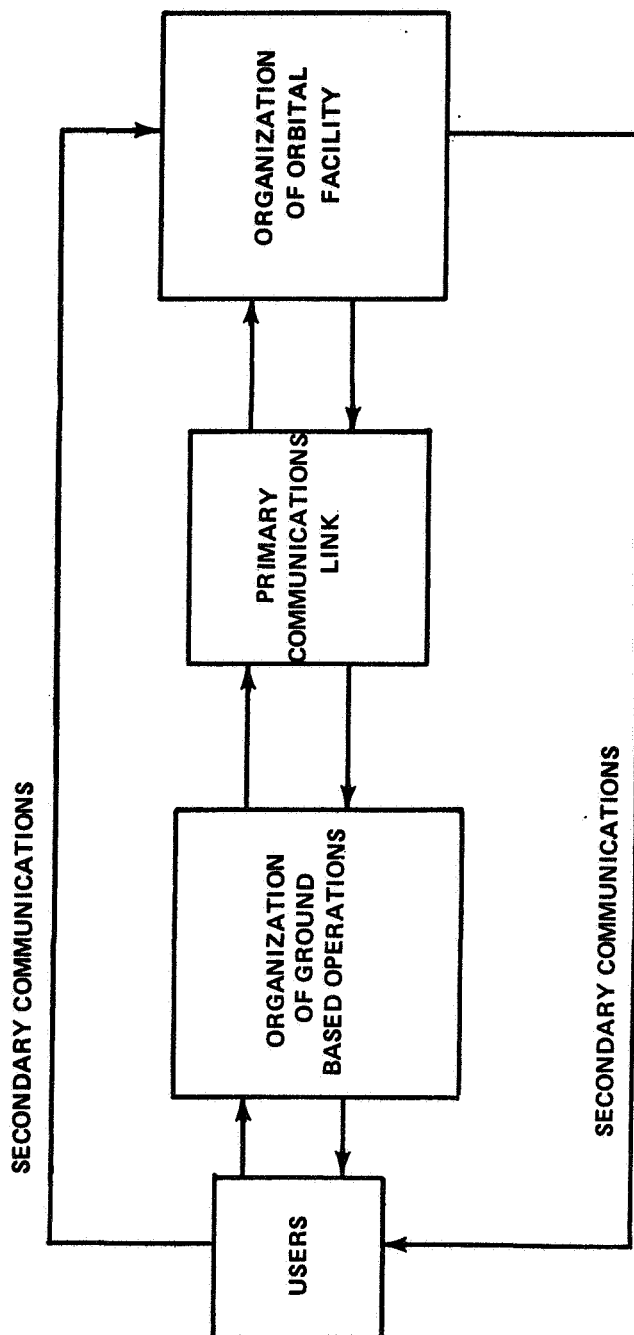
Primary Communication Links -- Telecommunications and data links to and from users and orbital facility and to and from system administrators and orbital facility. (This element can, but does not have to, include transportation to and from orbit.)

Secondary Communication Links -- Direct telecommunication and data links between user and orbital facility.

Orbital Facility -- The organization and administration of the orbital facility, facilitation of user needs and control of primary communications links.

Exhibit 4-6

STRUCTURE OF ORGANIZATION OF AN ORBITAL FACILITY SYSTEM



User

In considering user impact on organizational design the principal tradeoff comes in relation to access to the orbital facility. Two factors can be identified that will influence the design. First, the number of users that have access to the system -- will it be very limited or relatively unlimited? If limited, this would mean that the organization will establish priorities for access and administer those priorities. Second, the kinds of use that the facility is designed and available for. Although we assume that materials processing will occur, highly radioactive materials may not be allowed on the facility. This means that the organization will establish restrictions and administer them.

Ground-Base Operations

In the organization of ground-based operations, one can identify two areas of tradeoff that can influence organizational design, ownership and national participation. Ownership of the system can range from purely private to purely public; national participation in the organization can range from unilateral (single) nation participation to international participation. The issues of ownership and national participation are not mutually exclusive. If international participation is encouraged, some nations ideologically prefer public ownership of enterprise rather than private; therefore, they would object to purely private ownership. COMSAT is a case in point. When the semi-private corporation was created, there was considerable criticism by other nations of a private U. S. corporation controlling the communication system of which they were to be a part. INTELSAT was formed to meet ownership and national participation criticisms of COMSAT.

Exhibit 4-7 shows how existing organizations may fit on the ownership and national participation continua. These "models" are not to be taken as definitive but only indicative of the relationships that exist.

Communications

The principal area of communications tradeoff is in control of the communications and data links. Control essentially means the ability to cut off or possibly censor the links. Communications can be completely unrestricted or, as a product of design, the orbital facility organization may have the ability to restrict communications through the links that it controls. The obvious alternative to this potential for control is the establishment of secondary communications links that are user controlled. However, a decision to design in alternative communications links is a major tradeoff in the organizational design.

Exhibit 4-7

GROUND-BASED OPERATIONS ORGANIZATION:

OWNERSHIP CONTINUUM	ALTERNATIVE MODELS	NATIONAL PARTICIPATION CONTINUUM
PRIVATE	ENTREPRENEUR	UNILATERAL/NATIONAL
	PUBLIC UTILITY	
	COMSAT	
	T.V.A.	
	INTELSAT	
PUBLIC	E.S.A.	INTERNATIONAL

The transportation system is another major dimension of the communication system for an orbital facility. As stated earlier, transportation to and from orbit can be included in the design of the organization, but a transportation system can also be considered a separate system with which the orbital facility system interfaces; e.g., NASA's STS. It is clear, however, that if the orbital facility system is autonomous of the transportation system, that relatively unrestricted access to the transportation system must be a basic assumption of the organizational design.

Orbital Facility Operations

The basic options are to make the orbital facility manned or unmanned. For an unmanned facility; the tradeoffs lie in the technological subsystems, selecting the best mix of hardware and software to accomplish the specific processing goals. The decision to use man, or recognizing that man can assist in optimizing the operations of an orbital facility, must include a recognition of the behavioral dimensions of the organizational design.

Two behavioral areas that involve organizational design trade-offs are authority relationships and individual participation. There are many authority relationships, but we will examine centralized and decentralized. Whether to delegate (decentralize) authority to the orbital facility or retain authority in ground-based operations is a substantial question that must be resolved in the organizational design of an orbiting facility. We must also consider individual participation. An individual's motivation or incentive to participate in an organization is a substantial element of organizational design [March - 58]. An individual's participation may be authoritarian (assigned without choice) or it may be voluntary.

Exhibit 4-8 shows how existing "models" or organization may fit on the authority and individual participation continua. As in our discussion of ground-based operations, these "models" are not to be taken as definitive but only as indicative of the relationships that exist.

Conclusions

In this system design study, some constraints have been adopted to guide conclusions of the design effort. Four of these constraints are relevant here:

1. No direct military involvement in materials processing in space.
2. No significant change in world social and political trends.
3. Number of people in orbit will be relatively small (12 or less).

Exhibit 4-8

ORBITAL FACILITY OPERATIONS ORGANIZATION

ALTERNATIVE MODELS		
AUTHORITY CONTINUUM		INDIVIDUAL PARTICIPATION CONTINUUM
CENTRALIZED	MILITARY (NAVAL) COMMERCIAL MARITIME (SHIP) FACTORY ELECTIVE	AUTHORITARIAN
DECENTRALIZED	PROFESSIONAL	VOLUNTARY

4. Payloads to and from orbit for materials processing will be modest, not exceeding Shuttle capacity.

No direct military involvement would make an orbital facility more open to users, particularly to international users; it also increases the possibility of multi-national participation in the organization. Communications can be more open, authority more decentralized and individual participation more voluntary.

No significant change in social or political trends probably favors public dominance of ownership (with provisions for private lease of facilities). It also appears to favor unilateral national participation (U. S. dominance), but with relative ease of access by Western/industrialized nations to participation in the organization. Continuation of present trends should also favor more open communications links within the system. In addition, it would indicate continued public ownership of transportation and one would expect individual participation to be voluntary.

A small number of people in orbit would indicate that the number of users would be limited; it would also favor limited national participation (U. S., with some participation by other nations; probably Western/industrial). A small number of people in space allows for more decentralized authority; especially, if most participants are professionals.

Modest materials processing payloads to and from orbit which do not exceed Shuttle capacity indicates that the users will be restricted to those interested in very high value or very high technology. National participation in the organization is, therefore, likely to be limited to industrialized nations using or seeking high technology.

A probable profile of the organization of the orbital facility system would be:

- ° National participation -- U. S. dominated, with strong ties to Western/industrial nations
- ° Access -- limited
- ° Ownership -- public, with working relationships with private users
- ° Communications -- open
- ° Authority -- decentralized
- ° Individual participation -- voluntary

Given the isolated and hostile environment of space, no single

model of a presently existing organization begs for consideration as the basis for designing an orbital facility system; however, the commercial maritime model, especially sea-going processing facilities, may provide a way of understanding the organizational design needs of an isolated/disconnected facility like that of an orbiting processing facility.

4.6 CONCLUSIONS AND RECOMMENDATIONS

The major conclusion reached by the organization task group is that the present organization must evolve in order to accommodate materials processing in space.

RECOMMENDATION: A ground transportation system using existing airline agents should be used to facilitate the flow of materials to be processed between factory and launch site.

RECOMMENDATION: The processing facility should be initially automated with evolution to a man-tended mode.

RECOMMENDATION: The Space Station should be government owned and organized in a civil-maritime manner along the line of a fish processing factory ship.

REFERENCES

CHAPTER 4

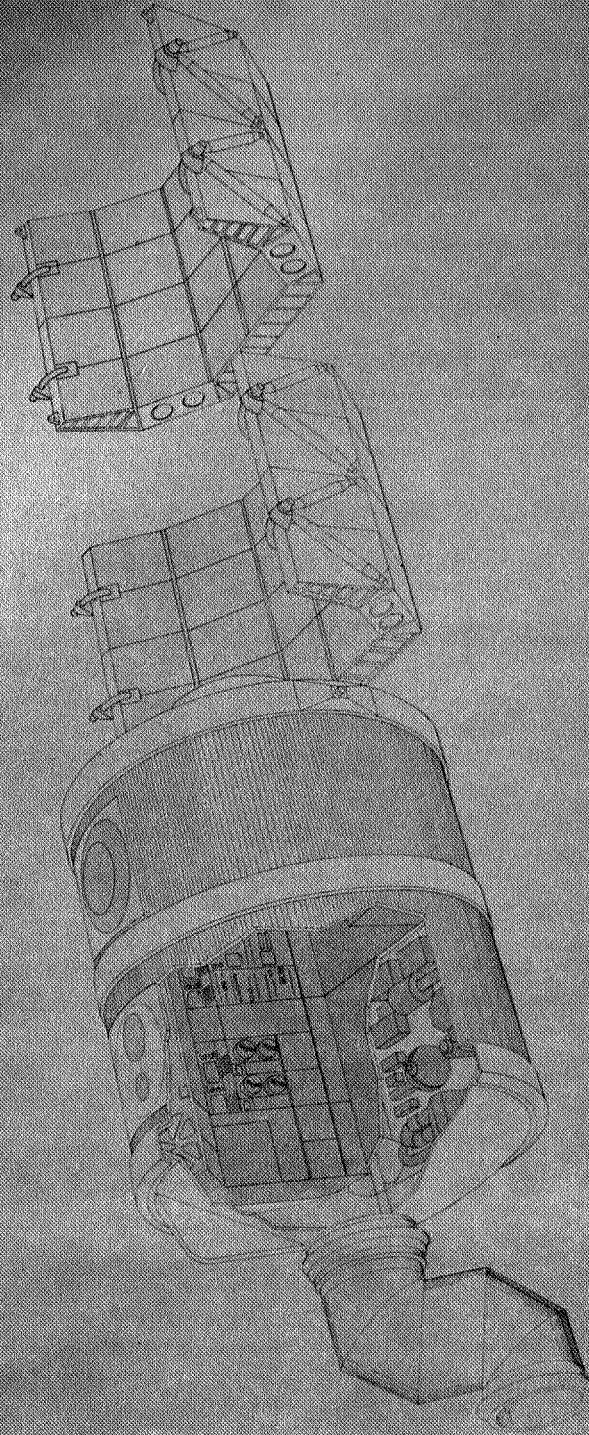
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MODULAR SPACELAB



MSFC-75-NA-2925-4B

CHAPTER 5

FUNDING

5.1 INTRODUCTION

Materials processing is one of six programs now planned for the Shuttle era. The program for materials processing already exists but present activities in space for this program are currently limited to experiments on the drop tower and on the space processing applications rocket (SPAR). Present planning for this program in the Shuttle era is somewhat vague, but trends in thinking are apparent. Promoting materials processing seems to center around pilot plant demonstrations in orbit. Such demonstrations would then be publicized to the business community as a means to attract private investment.

Like most programs awaiting the advent of the Shuttle, the program in materials processing is a low-level activity. Funds in 1977 are about \$6 million, and it is tentatively planned that the annual budget will increase to about \$15 million by the advent of the Shuttle flights in 1981 - 1982.

It must be emphasized that in manufacturing a high-technology product, several hundred to several thousand distinct steps in operations may be required. As indicated in Exhibit 5-1, one of those steps or operations may require the use of the space environment. In that case, that portion of the finished product requiring such an environment would be orbited for the processing of that step. All other steps or operations would be performed in routine manufacturing operations on Earth. This step, therefore, becomes a very expensive part of the production process.

The plan is that this program will initially be funded by NASA, and, hopefully, at some future date the major funding will shift to private sources. There are many precedents for phasing private capital into a project and phasing government funds out. A recent example is the COMSAT program, which provides both a precedent and a model for future programs.

Generic requirements for funding seem to be limited to sources and planning, as indicated in Exhibit 5-2; these requirements generate the indicated alternatives.

In the following discussion, NASA's funding history will be reviewed. Then, current funding-source alternatives will be discussed as well as

Exhibit 5-1

UTILIZATION OF SPACE ENVIRONMENT IN PRODUCT MANUFACTURING

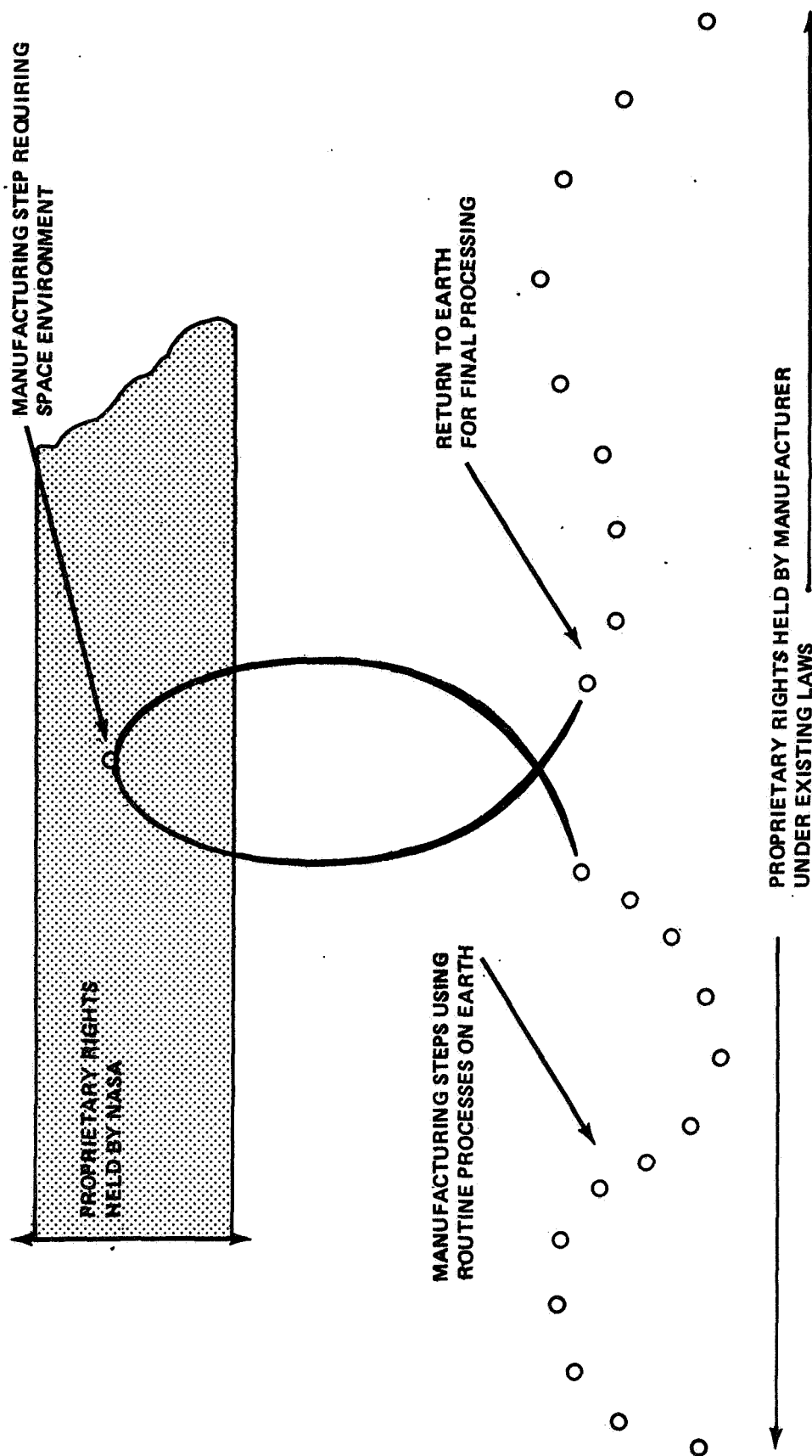
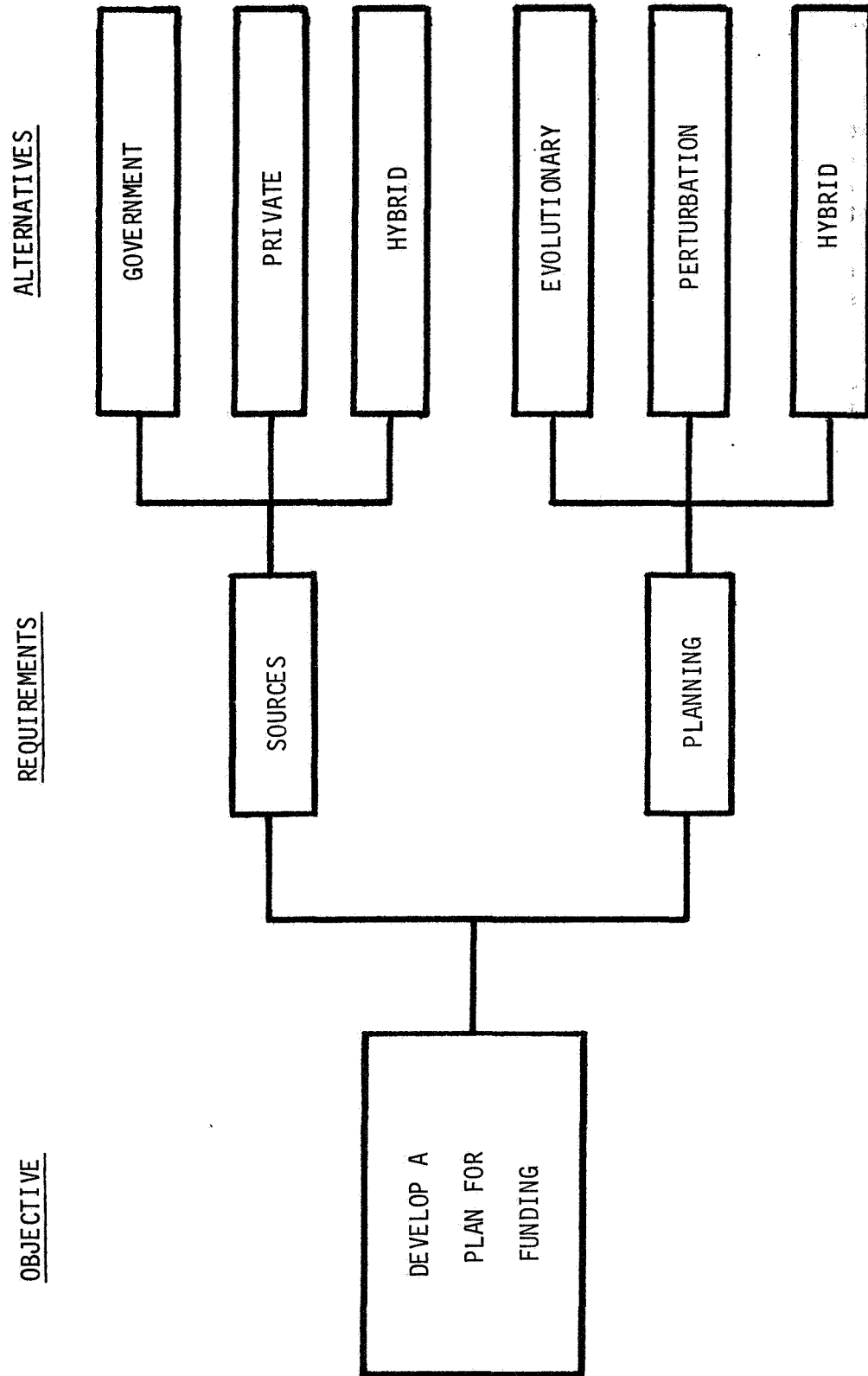


EXHIBIT 5-2
SYSTEMS DIAGRAM FOR
FUNDING REQUIREMENTS



current planning for funding perturbing activities. Finally, recommendations are made with respect to future funding strategies.

5.2 FUNDING HISTORY

Past funding in materials processing, including the present program of tower drops and SPAR experiments, has been provided almost without exception by the U. S. Government through NASA budgeted funds. At its peak, about 1967, the NASA budget was about \$6 billion, declining thereafter to its present level of \$4 billion. As a consequence of high-intensity "Mission-oriented" funding, planning for future funding within NASA has been a sporadic activity. As indicated in Exhibit 5-3, planning activities have been largely centered in 3 periods, with almost total discontinuity between those periods.

The uncertainties surrounding NASA's permanent role following the Apollo program, combined with effects of the Vietnam war, post-Watergate era and three presidential administrations in three years, are reflected in NASA's currently indecisive planning and programs. No fault or blame is associated; these are simply a few of the conditions which NASA planners have faced over the past few years. A discussion of the effects of such conditions is included later in this chapter.

NASA enjoys the recognition of being one of the most effective and efficient government agencies in utilizing program budgets. On an overall average, 3 dollars out of 4 which are allocated to NASA programs will go into the program, the remainder going into NASA overhead and administration costs into associated or supporting research and other support activities. Such a proven ability should aid immeasurably in coaxing funds from an increasingly frugal Congress in the coming years. See Appendix B for NASA funding, 1959 - 1976.

5.3 FUNDING ALTERNATIVES

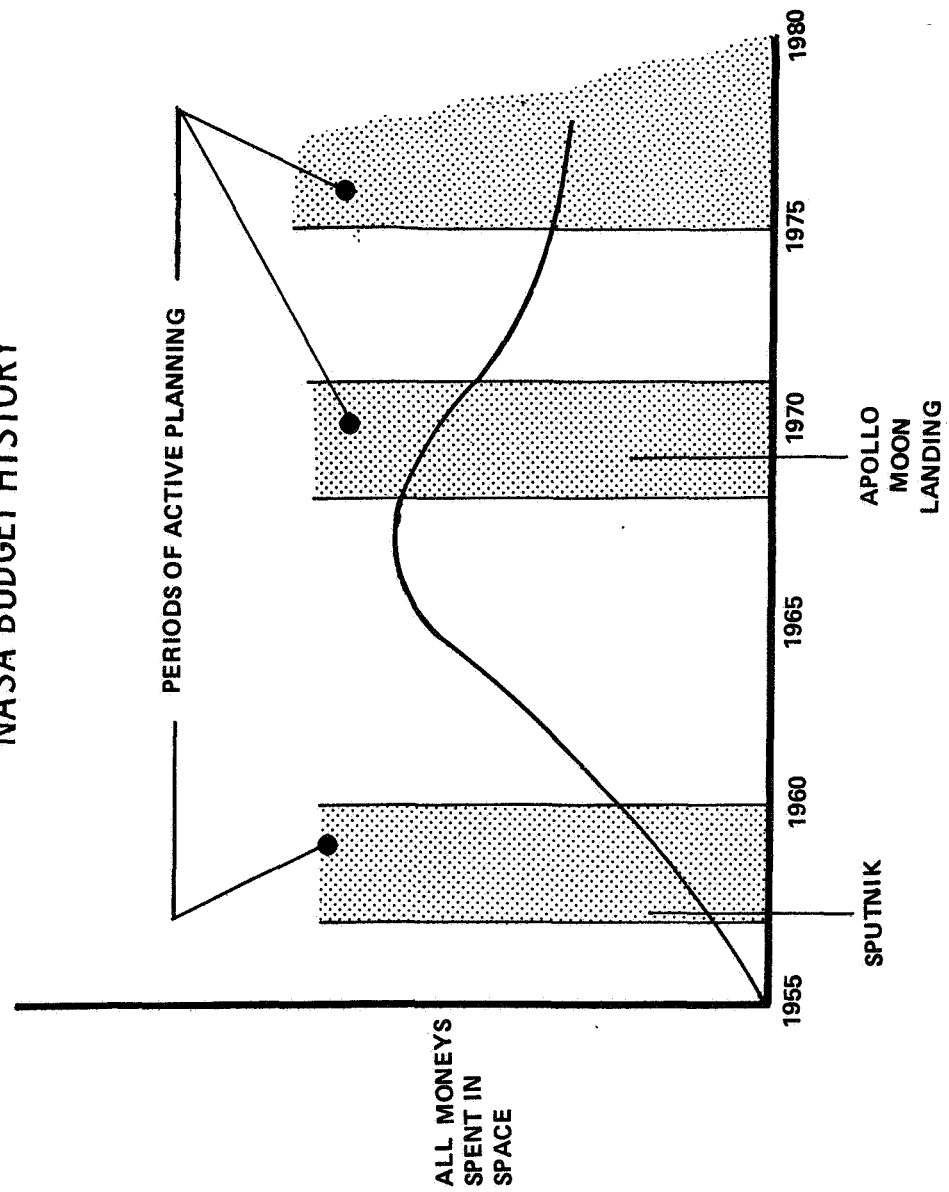
Of the obvious source alternatives, a hybrid system combining a maximum of private venture capital with NASA providing the transportation system seems most desirable. ERDA/NASA projects, DoD/NASA projects or projects initiated by foreign governments in conjunction with NASA would also be possible. See Section 7.4 also.

5.3.1 GOVERNMENT

Government funding solely from government sources seems inevitable for the initial years of research and development in materials processing in space. During those years, it also seems inevitable that the manufacturing processes unique to space will be defined and developed in great detail. If, as a consequence of such research, a viable and profitable product is discovered, then so much the better. There is no guarantee or even a promise, however, that a profitable product will ever be discovered (for use on Earth) which requires the space environment for one of its manufacturing steps.

Exhibit 5-3

NASA BUDGET HISTORY



Even if no products ever evolve which might warrant further development, government funding for R&D is strongly justified. See Section 7.1. At some future date, possibly near the year 2000, it will almost certainly become necessary to construct large structures in space (or on the moon) from extraterrestrial materials. In such cases, the manufacturing processes must be well defined to include processing, manufacturing, fabrication, assembly and field erection techniques. Crash programs are wasteful; a continuing program of R&D beginning in the early years of the Shuttle era would help to avoid a crash program in manufacturing and processing when such information is needed.

It is noted that the budgets planned for materials processing are program budgets. They do not include funds for transportation, orbiting space labs, or major components which are funded from other budgets. The program budgets include funds directed at accomplishing a program including development and fabrication of all equipment directly related to that program.

5.3.2 PRIVATE

Current attitudes in NASA indicate that significant amounts of private funds will not likely be invested in the R&D phase of materials processing. More likely, private capital will follow when proven, reliable, and economical processes or products have been developed by others. The high risk, the long lead times, the fast development of Earth-bound technology, and the lack of proprietary rights serve to discourage private investment.

Present laws concerning patents and disclosures tend to discourage private cooperation in government R&D efforts. Stated simply (probably oversimplified), if the U. S. Government invests money into a development, the proprietary rights accrue to the government. There are such things as patent waivers granted by the Government to private inventors, but the general attitude of distrust of the government still serves to discourage enthusiastic participation. Of the 21,000 patents awarded to NASA during the Apollo program, there were about 1200 requests for waivers by the contractors of which about 900 were granted.

Present trends in the Government indicate that future patent laws will be directed toward producing more uniformity rather than less uniformity. Consequently, the granting of patent waivers will likely decrease rather than increase. Considering the billions of dollars that the U. S. Government spends in R&D in agencies other than NASA, a change in the laws to suit NASA's needs seems remote.

The key word in understanding the reluctance of industry to participate in Government-sponsored research is distrust. Over many years of conflicts, industry has chosen not to expose itself to suits involving proprietary rights. For large industrial concerns such suits may be burdensome; for small concerns such suits may be disastrous.

The assignment of proprietary rights to the government should not be considered a permanent block to utilization of space in materials processing. As indicated in Exhibit 5-1, the amount of processing done in space in manufacturing a particular product can be expected to be a very small amount of the total time and effort. Where the rights are extended equally to all prospective manufacturers, it could be argued that the policy could actually encourage several manufacturers to produce competing products.

5.4 PERTURBATIONS IN FUNDING

In the event a viable, profitable product is discovered for processing in space, present planning leans toward an infusion of funds to develop the product, to be subsequently diminished to zero as private capital takes over the required funding. A typical example of such impact funding is presented in Exhibit 5-4.

There is currently some speculation that the discovery of one such product would produce a demand for facilities which would provide a "drag" to pull other products or processes into space. Such a sequence of events is obviously possible, but by no means inevitable. Take, for example, the glass microballoons proposed for use in laser fusion. If their need should ever be established, the volumes required would be in the millions per day. Obviously, DoE would simply buy its own specially designed and equipped Shuttles to produce the balloons, with no further dependence on NASA other than launch site and landing facilities.

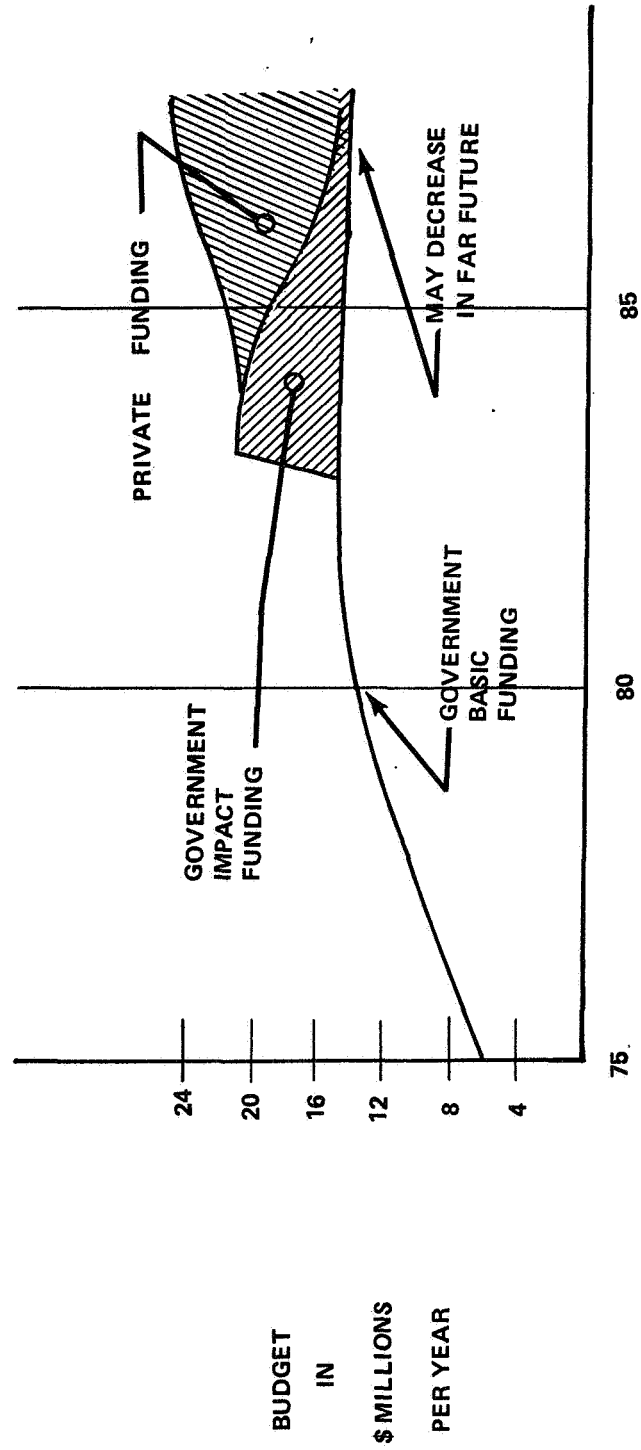
Referring again to Exhibit 5-4, there is no practical limit (other than Shuttle capacity) as to how many perturbations could be added on top of the R&D base load as shown, so long as private industrial concerns take over the burden. At some future date, it is entirely conceivable that with a multiplicity of products, the private funding could be many times the government R&D funding.

To summarize the current situation:

- ° Spending for NASA programs is efficient.
- ° Materials processing is expected to be funded at low-levels through the early years of the Shuttle era.
- ° NASA involvement in materials processing is oriented toward seeking products suitable for manufacture.
- ° Pilot plant manufacturing on a limited scale is included in present thinking.
- ° In all NASA involvement, rapid and full dissemination of developments is an essential mission requirement.
- ° No attempt to recover development costs of the Shuttle is now being considered.

Exhibit 5-4

EFFECT OF PERTURBATIONS ON BASIC R&D FUNDING



5.5 EVOLUTIONARY PLANNING

NASA's planning for materials processing in space follows an evolutionary scenario. It assumes a step-by-step scientific approach to proof-of-principles experiments that can justify investments in space activity by private organizations [NASA - 77-1]. "It is later envisaged to"...transfer experimental operations from Shuttle-Space-lab missions to a future space station" [NASA - 77-2]. Given the vagaries of long-range planning, this evolutionary approach seems very sensible, but its assumptions deserve closer scrutiny.

The evolutionary approach assumes the availability of funds to support materials processing experimentation, the discovery of a number of candidate products and the subsequent funding for the development and operation of one or more multipurpose space facilities. This set of assumptions, in turn, is based on the expectations of the NASA budget level, its division among various programs and a Shuttle traffic model.

The thrust of the evolutionary approach is technological evolution within a long-range projection of short-term funding trends. According to NASA's five-year plan, "This plan will be profoundly influenced by scientific discoveries, by changes in international policy and national priorities and by technological progress" [NASA - 77-3]. The cited plan shows sophistication in the scientific and technological areas and a lack of foresight on the effects of international policy and national priorities on the space effort. This lack of foresight seems almost inevitable because of the politics of the budgetary process. But some national or international events will require a quick response, space-related action that NASA will be unable to provide because of inadequate planning. Flexibility of planning in one area and rigidity in another may prove to be a combination that the nation will come to regret. It is the purpose of this section to suggest an alternative.

5.5.1 PLANNING HISTORY

As previously noted in Section 5.2, NASA has suffered the effects of roller coaster budgets. With the end of the Apollo program, NASA underwent drastic reductions in programs and personnel and acquired the mentality of the siege. Reduced funding produced short-range planning. It is only recently, with the approach of the Shuttle era, that NASA regained institutional vitality and re-emphasized long-range planning.

In the meantime, NASA's programs undergo a rigorous scrutiny by both OMB and Congress. A scrutiny that has forced it to strive for maximum efficiency, to the extent that "...NASA does, to a large degree, zero-base its Research and Program Management..." [Hearings - 77]. The very efficient use of taxpayer funds is to be commended. But, with all due allowances made for the less precise measurements

of efficiency inherent in less technical areas, it would be even more commendable if the same standards were applied to the entire array of federal programs. But then, rigorous standards are only imposed on unpopular programs. And this points to NASA's political problems.

5.5.2 BUDGETARY PROBLEMS

NASA's political problems stem from the fact that it has a limited constituency and a negative public image. NASA has a limited constituency with vested interests because of the limited size of its budget. The direct beneficiaries of NASA spending are largely limited to the aerospace industries, their contractors and their respective local governments, and to research organizations and universities. Even more serious is the limited constituency of users and of direct beneficiaries of NASA programs. These include the Departments of Defense and of Energy, airlines, and various segments of the public and private scientific community, some of the latter in direct competition with NASA for dwindling federal R&D funds. In the case of LANDSAT, which provides tangible NASA benefits to many groups, some of them for the first time, they have yet to gel into a workable coalition that could influence the increased funding for similar programs.

NASA's negative public image needs little documentation. Polls in the seventies have regularly shown that when the population was asked which federal programs should be curtailed, more than half of the answers included the space program, foreign aid and "welfare cheats". Even if allowing for a liberal definition of the latter, the total expenditure on these programs hardly exceeds 5 percent of the federal budget. Thus, even the total elimination of these programs would contribute only marginally to the solution of problems that are perceived as more pressing.

The results of these public opinion polls reflect the educational levels of the adult population. This includes 25 percent of functional illiterates and 10 percent of marginally functional literates. These two groups account for most of the non-voters -- roughly half of the adult population. If, unexpectedly, these two groups turned to massive voting, it would produce significant changes in national priorities, including the space program. It may be facile to dismiss the unpopularity of the space program with the less educated third of the population, but lack of education will not explain the similar disenchantment of many segments of the literate, and voting, public. Many who agreed with President Nixon that the landing on the Moon was "the greatest event since Creation" now hold that \$20 billion is too high a price to pay for some Moon rocks. This profound change of perception is a result of a change in mood. We will now examine the causes of this change in mood and its effect on the space program.

5.5.3 SOCIAL MOOD AND THE SPACE EFFORT

The analysis of the mood of the nation, of the so-called Zeitgeist, is a very imprecise undertaking, performed only at the risk of the professional reputation of the analyst. Any analysis going beyond the simple statement of probable causes must delve on their multiple mutual interactions, on their effects on social values and beliefs, and on the distribution of power and income in society. Such analysis is beyond the scope of this section. We will thus limit ourselves to a simplified tracing of the main causes and effects that influenced the direction of the federal budget and the support for the space program.

5.5.3.1 CAUSES

1. The Vietnam War

- Economy -- Because of its unpopularity, the war was not financed by taxation, but mainly by inflation. The ensuing countermeasures to inflation introduced the United States to the phenomena of stagflation (stagnation and inflation), a leading cause of the recession.
- Foreign Policy -- Opposition to the war led to a loss of consensus on foreign and defense policy and to a mentality of siege in the White House. This led to the abuses jointly labeled as Watergate, which led to the further erosion of credibility in government, including public statements on the benefits of the space programs.
- Defense Policy -- Opposition to the war brought out opposition to the warriors and to their providers, the so-called military/industrial complex. Because of its close functional relationship with both, NASA became suspect through guilt by association.

2. The Civil Rights Movement

- Encouraged the organization of minorities -- What began as the redress of grievances for one racial minority encouraged the splitting and organization of parts of the population into sets of often overlapping minorities. These minorities presently include race, national origin, language, gender, the old, the young, the physically handicapped and maybe even the homosexuals. Some of these minorities are flexing their newly-developed organizational muscles and vigorously competing for federal funds.
- Encouraged the value of collective equality of groups.

3. Vietnam and the Civil Rights Movement

- Gave respectability to protests
- Encouraged participatory democracy -- Given a set of laws with conflicting effects, organized minorities may influence the selective enforcement and funding of laws, often in opposition to the will of the majority.
- Encouraged changes of priorities -- The changes gave rise to the environmental movement and eventually to the National Environment Protection Act and to the Environmental Protection Agency. The changes also gave rise to anti-technology sentiments.

4. Oil Embargo

- Significant foreign policy impact
- Large increase in oil prices -- These changes dramatized the energy crisis and triggered the most severe worldwide recession since the 1930's.

5. Recession

- Documented cause of national pessimism
- Curtails investment and production
- Inhibits long-range planning

5.5.3.2 EFFECTS

After the brief examination of the main causes that changed the optimistic mood of the nation in the early 1960's -- that launched the Apollo program -- to the deeply pessimistic mood of the 1970's, we can examine the specific effects of social mood on the space program. Three components of social mood are considered: the relationship between man and nature, man and nation, and nation and the world.

1. Man and Nature

The first section of Exhibit 5-5, Social Mood and Space Effort, considers the impact of mood on the perception of the effects of man's use of technology on the environment and natural resources and their consequent effect on the desirability of economic growth.

Pessimism

Perhaps the best illustration on the effects of pessimism on the perception of the effects of technology on nature is provided

Exhibit 5-5

SOCIAL MOOD AND SPACE EFFORT						
MAN AND NATURE						
MOOD	VIEW OF THE FUTURE	TECHNOLOGY AND ENVIRONMENT	TECHNOLOGY NATURAL RESOURCES	TECHNOLOGY AND ECONOMY	VIEW OF SPACE	EFFECTS ON SPACE EFFORT
PESSIMISM	STATIC	NO GROWTH	NO GROWTH	NO GROWTH	CLOSED SYSTEM	UNFAVORABLE
OPTIMISM	DYNAMIC	TECHNOLOGY BASED GROWTH	TECHNOLOGY BASED GROWTH	TECHNOLOGY BASED GROWTH	OPEN SYSTEM	FAVORABLE
MAN AND NATION						
MOOD	PREDOMINANT VALUE	LEADS TO EQUALITY OF	CRITERIA OF GOVERNMENT PROGRAMS	DIRECTION OF GOVERNMENT PROGRAMS	LEADING TO EMPHASIS ON	EFFECTS ON SPACE EFFORT
PESSIMISM	COLLECTIVE EQUALITY	RESULTS	RELATIVE	DISTRIBUTION OF INCOME	CONSUMPTION	UNFAVORABLE
OPTIMISM	INDIVIDUAL LIBERTY	OPPORTUNITY	CONCRETE	ECONOMIC GROWTH	INVESTMENT AND PRODUCTION	FAVORABLE
NATION AND WORLD						
MOOD	POLICY TYPE	DEFENSE POSTURE	OIL IMPORTS	RELATIONS WITH INDUSTRIAL COUNTRIES	RELATIONS WITH UNDEVELOPED COUNTRIES	EFFECTS ON SPACE EFFORT
PESSIMISM	POST-VIETNAM SYNDROME	ITEM EQUALITY	INCREASING	COOPERATION AND CONFLICT	INDIFFERENCE	UNFAVORABLE
		STATIC BALANCE OF POWER	PURSUIT OF INDIVIDUAL INTERESTS	BALANCE OF POWER	BALANCE OF POWER	
OPTIMISM	RATIONAL NATIONALISM	OVERALL PARITY	DECREASING	COOPERATION & COMPETITION	RATIONAL HUMANITARIANISM	FAVORABLE
		DYNAMIC USE OF SPACE	MORAL EQUIVALENT OF WAR	TRILATERALISM	SPACE RELATED ASSISTANCE	

by the book, "Limits to Growth", from the Club of Rome. The thesis of this highly influential book is well known and needs little elaboration. In essence, it states that given the continuation of present economic and population growth, mankind will be faced in one to two centuries from now with one or more of the following: mass starvation, environmental suffocation or depletion of natural resources, leading to a return to pastoral life. One of its assumptions is that the ill-effects of technology cannot be remedied by better technology. Its prescription is slower economic growth and massive redistribution of income.

The errors of this thesis have been documented by others elsewhere. As a result of these criticisms, the thesis has undergone two major revisions. But the thesis is highly indicative of mood. Here is Malthus with a vengeance. But, whereas Malthus predicted only starvation for the poor, the Club of Rome foresees doom for all. It is ironic that the credibility of the attack against technology -- and by implication against the space programs -- is based on the manipulation of symbols of modern technology; the computer and the view of space ship Earth from the Moon!

Optimism

It is clear that the widespread discussion in the United States and abroad on the themes addressed in the book, "Limits to Growth", has served a useful function. Partly as a result of the above, we now have environmental legislation, an environmental bureaucracy and the environmental impact statement. And with the energy crisis serving as a catalyst, the United States has begun to address the complex problem of reducing waste in the use of natural resources. Economic growth will doubtlessly continue, but based on cleaner and more efficient technology. The return towards an optimistic appraisal of the relationship between man and nature may return gradually with the reassertion of faith in traditional Yankee ingenuity, or more abruptly, through technological responses to nature's challenges. And that technology will be mainly space technology.

2. Man and Nation

The second section of Exhibit 5-5, considers the impact of mood on the perception of the proper relation between the individual and society. The mood affects the classical philosophical difference between socialism and free enterprise; between collective equality and individual liberty. This ongoing debate has a direct impact on the funding of the space program; one philosophy leads to short-term perspective and to consumption, the other to long-range perspective, research, investment and production.

Pessimism

The events of the last 15 years have had an impact on the traditional American optimism. Vietnam, the polarization of society, the persistence of social problems, the clash of values, the oil embargo, Watergate, inflation and recession -- their cumulative effect has turned the nation to a pessimism not seen since the depression. In 1973, only 53 percent of individuals were satisfied with the future facing themselves and their families [NY Times - 77-1]. Massive loss of confidence in the future focuses the attention on the present. Loss of faith in one's individual destiny, drives one to the shelter of the group. The instinct of the herd takes over.

Once that pessimism forces individuals to accept the pre-dominant value of collective equality, it ensues a number of corollaries. If individual efforts account for little, it follows that the appropriate standard of social justice is not of individual merit but of result, as measured by some collective quota. Government programs of assistance to individuals become influenced as much by relative standing as by concrete needs. Federal programs geared significantly to the maintenance of relative standards become enmeshed in a vicious circle where the mutual expectations of government, voters and traditional and new interest groups, result in the funding of additional similar programs. Collective equality acquires the legitimacy and the funds previously reserved for defense and the pork barrel. Pessimists do not look up to the sky for answers.

Optimism

The return towards an optimistic appraisal of the relationship between man and nation will probably resume with the reassertion of the traditional American value on individual liberty. The cited poll shows that the number of individuals who were satisfied with the future facing themselves and their families had increased from 53 percent in 1973 to 64 percent in 1977 [NY Times - 77-2]. It also indicates that the main concern of the American family is the family budget. It is reasonable to assume that if the economy continues on its present recovery from the worst recession since the Great Depression, that in 3 or 4 years from now, 3 out of 4 families will have regained their faith in their own futures. Optimism in one's self engenders optimism for the nation. This reinforces an economic growth based less on government-induced and financed demand for consumer goods and more on investments in capital goods in the private sector. This may lead to a situation where public investment in space may be good economics and good politics.

3. Nation and World

The final section of Exhibit 5-5 considers the impact of the mood on the perception of the relations between the nation and

the world. This relation is crucial to the space program which by its very nature is international in scope.

Pessimism

The present era of U. S. foreign policy has been referred to as the period of the post-Vietnam syndrome. Having suffered in Vietnam the effects of excessive optimism, prevalent in the Kennedy years, the U. S. presently suffers from the effects of excessive pessimism. Vietnam shattered the previously held domestic consensus on foreign policy. Our present era is characterized by an absence of definition of national interest, of internally consistent national goals, and of a national doctrine of allocation of means to ends. For lack of alternative policies, we have reverted to the mechanistic application of the classical balance of power model. This model leads to behavior that is mainly reactive to events. It also discourages the creative application of space programs to the support of foreign policy goals.

The thrust of the defense policy of the previous administration has been the achievement of overall parity with the Soviet Union, a parity in fact and in appearance. Therein lies a contradiction. Appearance of parity is vital because of its political and diplomatic effects, but if overly stressed it may lead to misallocation of resources. This means a matching of major categories of defense units and hardware without giving adequate consideration to their effective military value. Examples include our posture in the SALT talks with mostly irrelevant quibbles on the range of a Soviet bomber, our gross waste of funds on useless reserve units in order to mark maps with paper divisions, etc. The chase of the shadow is the council of pessimism. It shrinks from putting the warrior in space.

Considering relations with industrial countries, the basic model of Kissinger's balance of power is the 5-power model. In this model the U. S., the Soviet Union, Europe, China and Japan engage in a minuet of cooperation and conflict over a variety of linked issues. The behavior implied in this model leads to good politics and clever diplomacy, but also to poor economics, questionable morality and utter confusion. Its pessimistic assumptions deprive the American people of a role beyond that of a balancer.

Nowhere is the pessimism of the post-Vietnam syndrome as evident as in the relations with undeveloped countries. Disappointment with the limits of our military power to enforce our choice of domestic regime in one country has led to indifference to all countries that lack economic power. Pessimism leads to indifference and to the abdication of a sense of mission.

Lack of domestic consensus on foreign policy goals fails to sublimate our individual interests into the common actions required

to stem the increase in oil imports and, hence, in our vulnerability to foreign pressures.

Optimism

The return towards an optimistic appraisal of the relationship between nation and the world seems to be well on the way. The wounds of the lost war are healing. A policy of rational nationalism is emerging in which optimum means are used to support feasible ends. The best example is provided by the recent decisions to abandon the B-1 bomber in favor of the cruise missile, and to neutralize the preponderance of Soviet tanks with the neutron bomb (a daring use of technology in areas amenable to technological solutions). Yankee ingenuity leads to the technological fix. And the highest technology is space technology. The Shuttle will provide us with the opportunity of excelling at what we can do best. It will improve our defense, assist our energy problems, provide channels of cooperation with industrial countries and of assistance to undeveloped countries. It will also gain us international prestige -- a welcome change from previous years.

5.5.3.3 PRESENT MOOD

American history may be described as the constant search for the proper balance between the three driving values of liberty, equality and progress. The events of recent history have polarized some segments of the population between those who define progress as equality and those who define it as liberty. The image of the former is static. It strives for a balance between man and nature, an equal balance among incomes, and for peace based on a balance of power. The image of the latter is dynamic. It strives to maximize man's use of nature and the economic rewards for individual merit, both at home and abroad. The essence of this philosophical conflict is over the rate of change -- one group fears future shock, while the other welcomes it. Space is a powerful symbol -- for one group it symbolizes the evils of society, for the other its salvation.

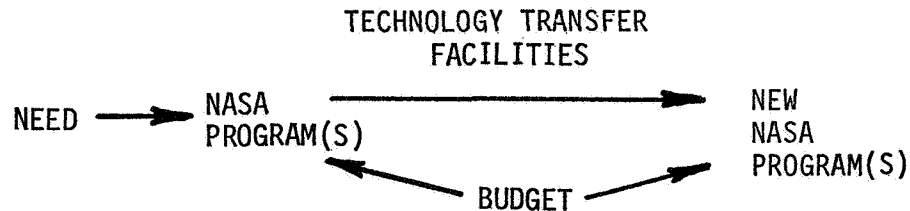
The future of the space program will hardly be determined by the outcome of this philosophical clash. The pragmatic and technologically jaded majority will cheerfully agree that both the universe and the poor will always be with us. The pragmatic approach is the incremental approach and well in consonance with NASA's evolutionary planning. If left to its own devices, NASA will probably perform its technological feats according to plan. But the world will not leave NASA alone. The institution should anticipate the change.

5.6 ENHANCED PLANNING

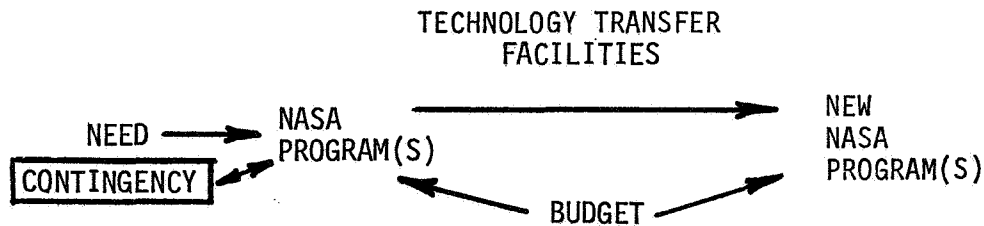
The Shuttle will decrease the cost and increase the variety of NASA's payload capabilities. The change in capabilities will produce

profound changes in NASA's socio-political environment. NASA will interact with new public and private interest groups and in different geographical locations. NASA will be able and expected to react to more events. Planning for the Shuttle era should include the new variables of the new socio-political environment.

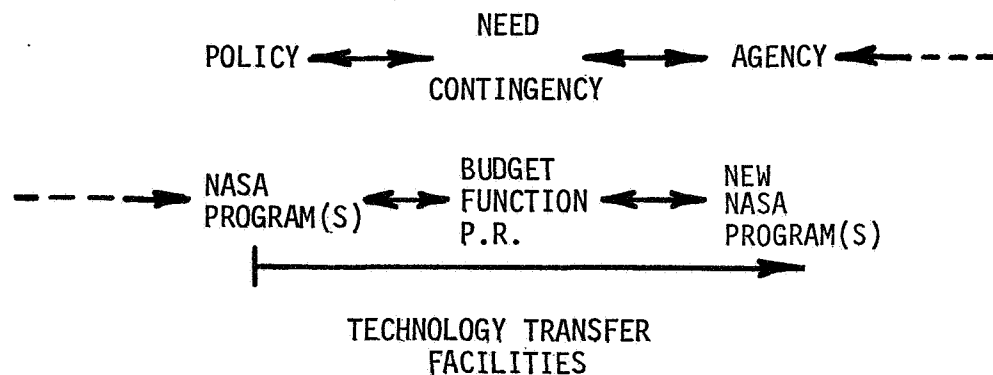
A simplified flow chart of NASA's evolutionary planning could be presented as follows:



The above flow chart illustrates the emphasis on technological evolution within certain budget constraints.



The second flow chart is augmented with the category contingency. This includes the planning for the reaction to foreign events and to acts of nature. This is the premium period on an insurance policy. It is strongly recommended that NASA include contingency planning on a budget line item and as a separate category in the basic planning document.



The third diagram is meant only for the use of internal agency planning. It illustrates the need to take into account the additional planning variables of NASA's socio-political environment in the Shuttle era. The two ends on all arrows imply that all the variables are related. In this diagram the planning allows for NASA programs to be

optimized for technological evolution and for institutional advancement. This might include the desire to establish a first program of cooperation with some agency (Office of Education) or a program to maximize public visibility (personal communication).

Exhibits 5-6 and 5-7 illustrate the methodology. The main horizontal categories -- Relations in Exhibit 5-6 and Policy in Exhibit 5-7 correspond to Exhibit 5-5, Social Mood and Space Effort. The purpose of Exhibits 5-6 and 5-7 is to examine the effects of one variable, perturbations, on the total space effort and on one program category, materials processing.

Processing

In Exhibit 5-6 we assume a perturbation, a severe climatic change. This produces a space-related response which improves NASA's total effort, but possibly decreases the funding for materials processing.

In Exhibit 5-7 we assume a perturbation in the form of Soviet actions that require manned satellite repair stations. This increases NASA's budget and pays for the development of technology affecting the indirect or joint costs of materials processing.

These charts serve only as illustration for the idea of incorporating variables not associated with technological evolutionary planning. It is proposed to marry the science of planning with the art of politics. But NASA needs help for the consumation of this marriage. The specific help is suggested in the next section.

5.7 CONCLUSIONS AND RECOMMENDATIONS

These are the conclusions:

- The space effort is presently influenced by the pessimistic mood of the nation.
- The opening of the Shuttle era will coincide with the renewal of traditional American optimism.
- There will be one or more severe perturbations that will upset NASA's long-range evolutionary planning.
- Materials processing will be affected by perturbations.
- Materials processing may be a cause of perturbations.

Materials processing is but part of the total space budget. NASA must sell the Shuttle to new interest groups. NASA must plan better for contingencies.

LEGEND: EFFECTS ON SPACE EFFORTS

Exhibits 5-6 and 5-7

TOTAL NASA BUDGET

BUDGET RELATED SUPPORT

INCREASE CONSTITUENCY WITH VESTED INTERESTS
IN NASA BUDGET

FUNCTION RELATED SUPPORT

INCREASE CONSTITUENCY OF DIRECT BENEFICIARIES
OF SPACE PROGRAMS

POSITIVE PUBLIC VISIBILITY

IMPROVE PUBLIC VISIBILITY AND IMAGE BY PROGRAMS
PROVIDING WIDESPREAD USE OF GOODS AND SERVICES
CLEARLY LINKED TO NASA IN THE PUBLIC'S VIEW.

MATERIALS PROCESSING BUDGET

DIRECT COSTS

R&D
MOLECULAR SHIELD
SPACE LAB
FREE FLIERS
DEDICATED SHUTTLE FLIGHTS

INDIRECT OR JOINT COSTS

SHARED SHUTTLE FLIGHTS
SPACE STATION WITH POWER MODULE
LARGE SPACE STRUCTURES
HLLV
PERFORMANCE OF MAN IN SPACE

Exhibit 5-6
EFFECTS OF PERTURBATIONS ON SPACE EFFORT
MAN AND NATURE

RELATION	EVENT	SPACE PROGRAM	EFFECTS ON SPACE EFFORT			
			INCREASE IN		AFFECT ON MATERIALS PROCESSING	
			BUDGET RELATED SUPPORT		POSITIVE PUBLIC VISIBILITY	
					INDIRECT	DIRECT
TECHNOLOGY AND ENVIRONMENT	SEVERE CLIMATE CHANGE	LARGE SCALE WEATHER FORECASTING	✓	✓		
		CLIMATE PREDICTION	✓	✓		
		TROPOSPHERIC POLLUTANTS MONITORING	✓			
		GLOBAL CROP PRODUCTION FORECASTING	✓	✓		
TECHNOLOGY AND NATURAL RESOURCES/ ENERGY	INCREASED COSTS OF FOSSIL FUELS	SOLAR POWER SATELLITE	✓	✓	✓	
		HAZARDOUS WASTE DISPOSAL IN SPACE	✓	✓		
		SPACE PRODUCTION LASER FUSION PELLETS	✓	✓		
	SEVERE BLACKOUTS	LUNETTA	✓	✓	✓	
		POWER RELAY VIA SATELLITES	✓	✓	✓	
TECHNOLOGY AND ECONOMY	INCREASED COSTS OF TRANSPORTATION	COMMUNICATION SATELLITES	✓	✓		
	BIOLOGICAL PRODUCT DISCOVERY	DIRECT AND INDIRECT MATERIALS PROCESSING FACILITIES	✓	✓	✓	✓
	OTHER MATERIALS PRODUCT DISCOVERY		✓	✓	✓	✓

Exhibit 5-7

EFFECTS OF PERTURBATIONS ON SPACE EFFORT (CONTINUED) NATION AND WORLD				EFFECTS ON SPACE EFFORTS				
POLICY	EVENT	AGENCY	SPACE PROGRAM	INCREASE IN	FUNCTION RELATED SUPPORT		AFFECT ON MATERIALS PROCESSING	
					BUDGET RELATED SUPPORT	POSITIVE PUBLIC VISIBILITY	INDIRECT	DIRECT
DEFENSE POSTURE	SOVIET ACTION	DOD	SPACE STATION	✓			✓	
			SHUTTLE NIK					
	US ACTION	DOD	MATERIALS PROCESSING	✓	✓			✓
			ANTI-SATELLITE WARFARE	✓			?	
			SATELLITE REPAIR STATION	✓			✓	
OIL IMPORTS	DOE CONTRACTS	NASA	DEMAND FOR MP PRODUCTS					
			Ⓐ WITHIN STS CAPABILITY	✓	✓			✓
			Ⓑ GREATER THAN STS CAPABILITY	✓	✓		✓	✓
	OIL EMBARGO	NASA	TERRESTRIAL SOLAR R&D	✓	✓			
			NON-SPACE ENERGY	✓	✓			
			SPS FEASIBILITY STUDY	✓	✓			
RELATIONS WITH INDUSTRIAL COUNTRIES	COOPERATION	NASA	HLLV FEASIBILITY STUDY	✓				
			AERONAUTICS - FUEL CONSERVATION	✓	✓	✓		
RELATIONS WITH UNDEVELOPED COUNTRIES	COMPETITION	NASA	JOINT FUNDING OF FACILITIES	✓			✓	✓
			MATERIALS PROCESSING	✓			✓	✓
	COOPERATION AND ASSISTANCE	D. OF STATE	INTERNATIONAL COMMUNICATION	✓	✓	✓		
			RESOURCES MAPPING	✓	✓	✓		
			ENVIRONMENT MONITORING	✓	✓	✓		
			LUNETTA	✓	✓	✓	✓	

There must be a funding strategy to maximize public support. Two recommendations are made.

RECOMMENDATION: In-house or contract study should be initiated to examine improvement of the institutional coordination with potential public Shuttle users. These should include:

- NASA interagency coordination
- NASA coordination with departments and agencies with presently weak institutional ties.
- NASA coordination with the Department of State to evaluate NASA attaches in industrial countries and NASA representatives to appropriate international organizations.
- NASA regional and/or state liaison offices with state governments.

RECOMMENDATION: Form an Advisory Committee on Public Relations with a charter to advise on PR techniques and on policy impacts on PR. In regards to the latter, it should advise on:

- The choice of policies to maximize positive public visibility.
- The effects of specific programs on various interest groups.
- The choice of programs to maximize the scope of benefitted interest groups.
- The reallocation of some public information and public relation resources from the technical community to other interest groups.

This recommendation is also a part of a recommendation made in Section 8.6, Space Program Awareness.

There must be contingency planning. Two recommendations are made:

RECOMMENDATION: Include contingency planning as a budget line item to cover the costs of cutting the lead time necessary to produce the more likely candidate systems. This should include:

- In-house A and B phase studies,
- Procurement of inexpensive critical components,
- Contractor planning of manpower, factory and equipment requirements, including permits, licenses and environmental impact statements.

RECOMMENDATION: Include contingency planning in NASA's long-range plan.

- Increase the time scale from 5 years to 8 or 10 years.
- Include a contingency planning section.
- When appropriate, incorporate the recommendations of the contingency planning section in the various program categories.

REFERENCES

CHAPTER 5

Hearings before a subcommittee of the Committee on Appropriations
House of Representatives, Department of Housing and Urban Development -
Independent Agencies Appropriations for 1978, Part 5 - National Aeronautics
and Space Administration, p. 962.

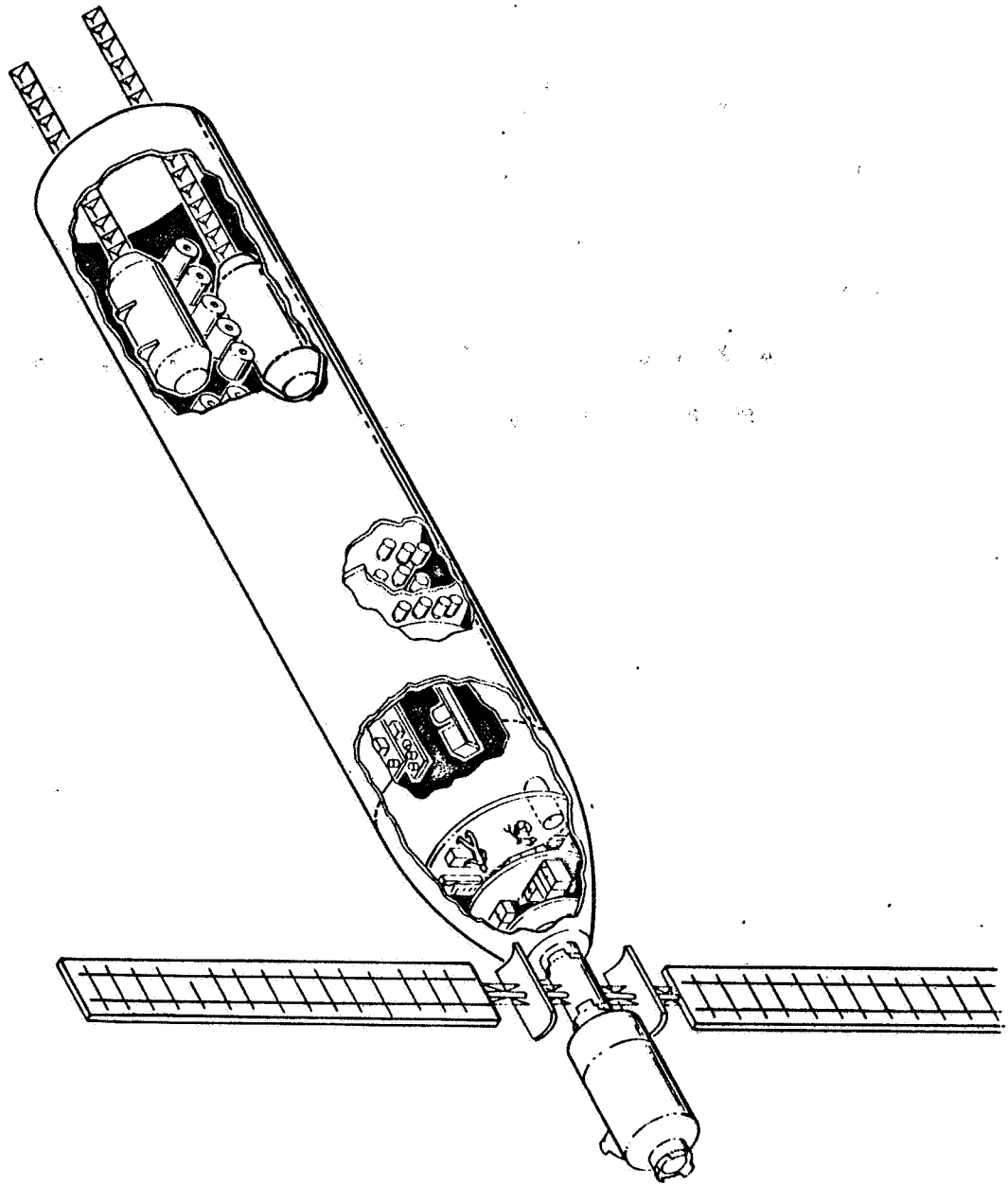
NASA Five-Year Planning, Fiscal Years 1978 through 1982, Draft, 1977, p.56.

NASA Five-Year Planning, Fiscal Years 1978 through 1982, Draft, 1977, p.57.

NASA Five Year Planning, Fiscal Years 1978 through 1982, Draft, 1977, p. 1.

New York Times, Gallup Poll, August 10, 1977.

FUTURE MODIFIED EXTERNAL TANK



CHAPTER 6

FACILITIES

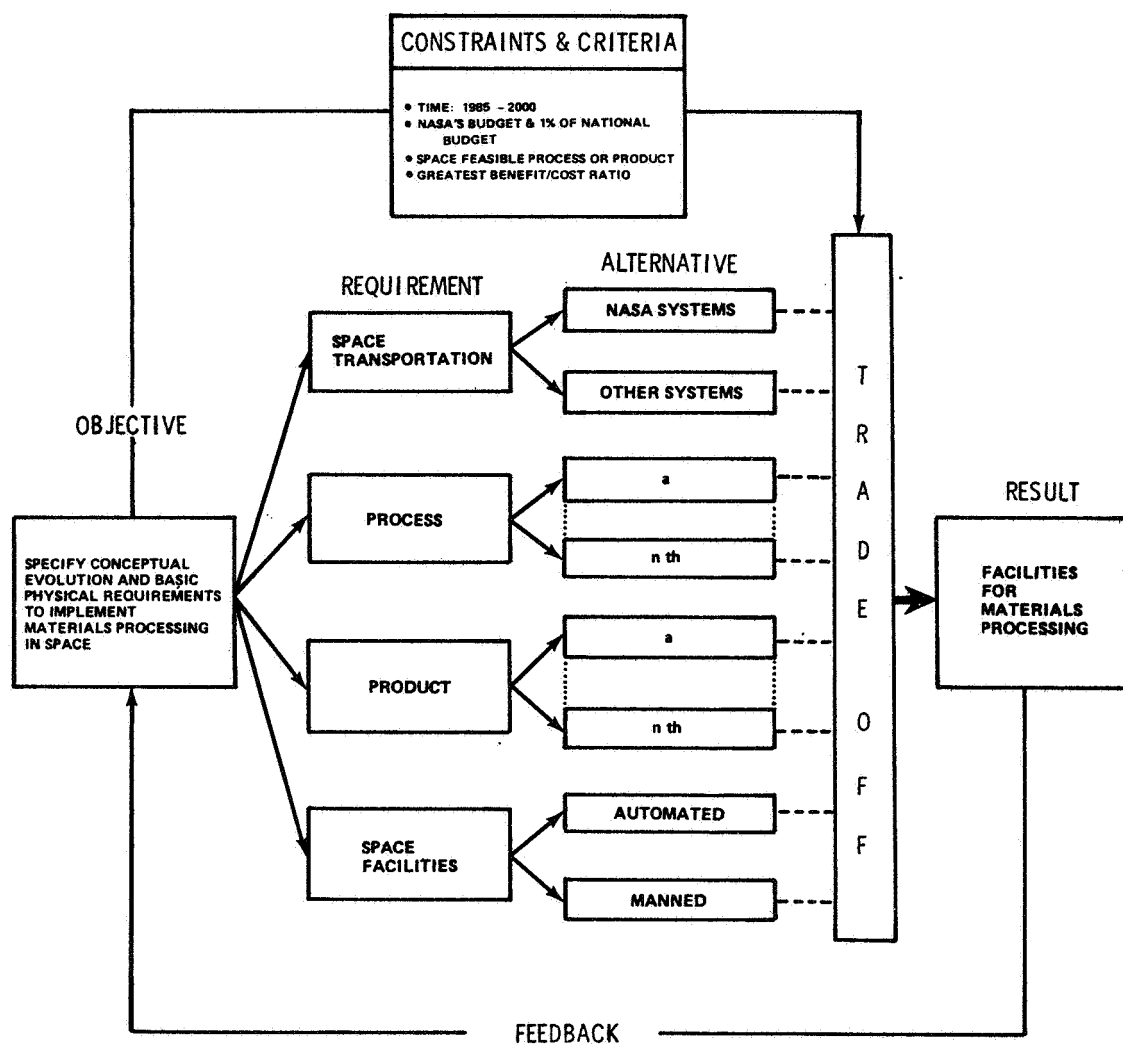
6.1 INTRODUCTION

The objective of the facilities study was to specify the conceptual evolution and basic physical requirements of facilities for the development of materials processing in space. Exhibit 6-1 is the diagram for the facilities subsystem and provides the structure for the discussion in this chapter. Three main areas were investigated, namely, the transportation between Earth and the facility, the actual physical facility concept, and the identification of potential processes or products. These areas were investigated from the viewpoint of attracting commercial ventures to space. The engineering details of such facilities do not appear to present any insurmountable technological problems, although they will depend on the particular type of manufacturing done. Consequently the study concentrated on the conceptual evolution of the transportation and facility requirements, particularly with regard to creating an environment in which industrial firms would be most likely to invest the necessary capital to make space manufacturing a reality. This problem of encouraging capital investment is at present complicated by three main considerations. First, the question of economically viable products is still unresolved. However, promising products have been identified as a result of the very limited space experimentation to date. A survey of these possibilities is presented in 6.3. A second complication is that of cost. In order to obtain significant industrial interest it will be necessary for the facilities to be designed so as to minimize the user cost, particularly during the initial development stages. The third complicating factor deals with security and the protection of proprietary interests. This involves a variety of legal questions involving the present patent laws, and has resulted in considerable distrust by industry of government programs in general. This problem is also discussed in Sections 5.3.2 and 8.4.2.

All of these considerations were taken into account in the design of the processing facilities and transportation systems. The transportation requirements are discussed in 6.2, which includes a survey of current proposals for post-Shuttle systems. In 6.4 the anticipated Shuttle capabilities for space research are surveyed, then a facility concept is presented for product and process development. The evolution of this facility throughout the Shuttle era is considered, and some post-Shuttle extensions are also developed. Finally, in 6.5 a more advanced manufacturing facility concept is presented.

Exhibit 6-1

FACILITIES SUBSYSTEM



6.2 SPACE TRANSPORTATION SYSTEM

6.2.1 INTRODUCTION

The objective of this section is to identify the transportation system elements, which are required in the facilities model, for transporting material, equipment, supplies, subassemblies and personnel from Earth to low-earth orbit (LEO) and transfer to geosynchronous-earth orbit (GEO) if necessary.

Exhibit 6-2 gives the transportation system diagram identifying the requirements, alternatives and controls needed to meet the transportation objective. The suggested transportation system will be discussed in 6.2.7.

Exhibit 6-3 shows the tentative flight readiness time table for the transportation vehicles, as well as the maximum payload capacity of some vehicles as indicated in parenthesis. During the early 1980's, the Shuttle-Spacelab combination will provide the principal support for space research and operations. Until 1985, no missions are expected to last longer than 30 days at which time the 25 kW power module likely will be available. Once the power module is available, one might reasonably expect the emergence of some form of permanently manned space station/base to provide continuous fabrication and assembly operations as well as more comprehensive research and development capabilities in orbit.

The next major step will be an upgrading of the baseline Shuttle system to a Shuttle-derived heavy lift launch vehicle (HLLV). The improvement of payload capability and operating cost is made by replacement of the two solid rocket boosters with a liquid rocket booster. Another possibility which could be made available sooner would be to substitute an expendable cargo carrier for the present orbiter and continue using the current solid rocket boosters.

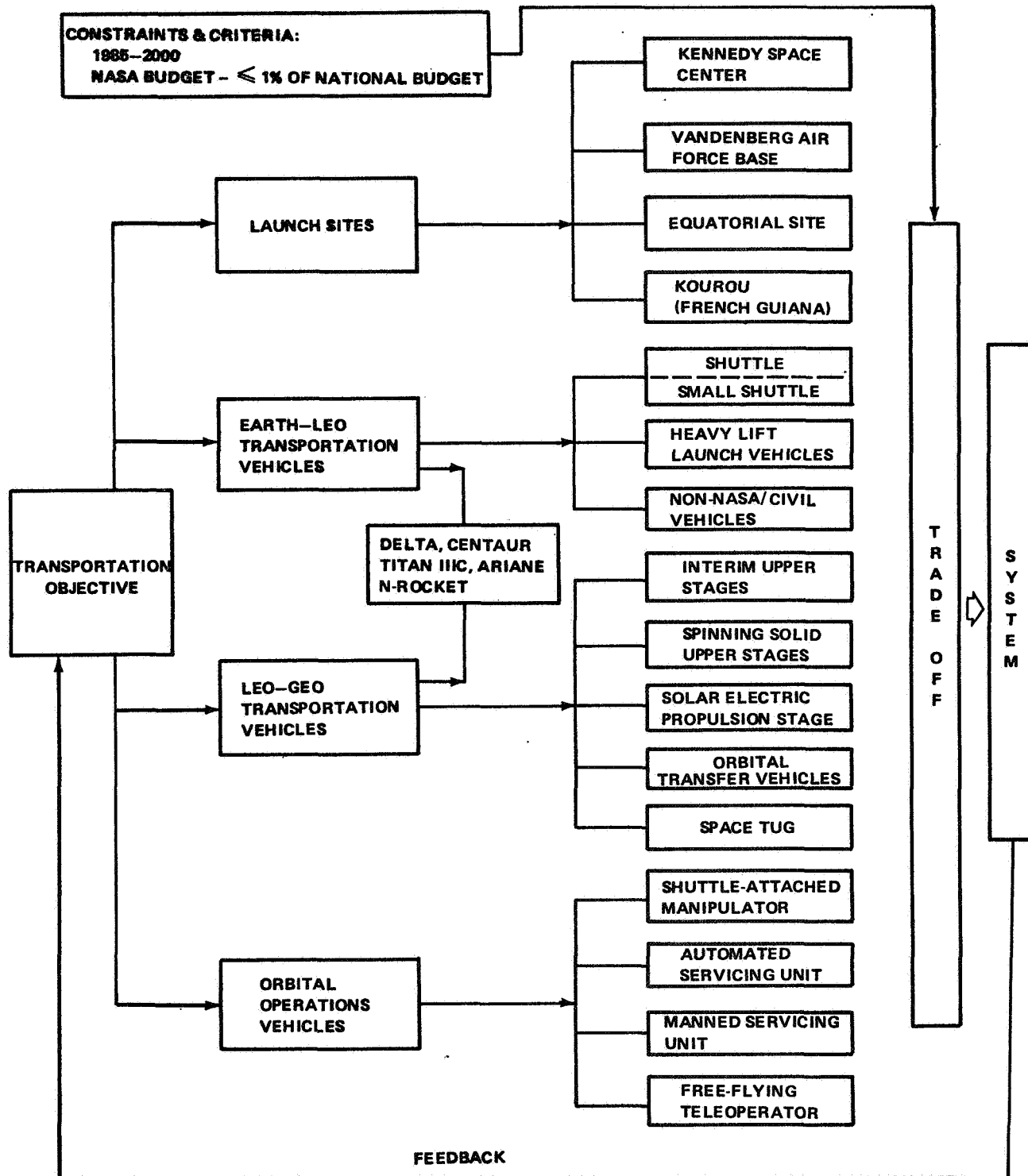
6.2.2 SHUTTLE TRAFFIC LEVEL AND PAYLOAD INTEGRATION

The Shuttle will be the primary (if not only) transportation system beginning in 1980 through the early 1990's. Exhibit 6-4 depicts the Shuttle traffic and payload models presently planned by NASA for the period 1980 through 1991. Both models cover domestic, foreign and commercial use of the Shuttle.

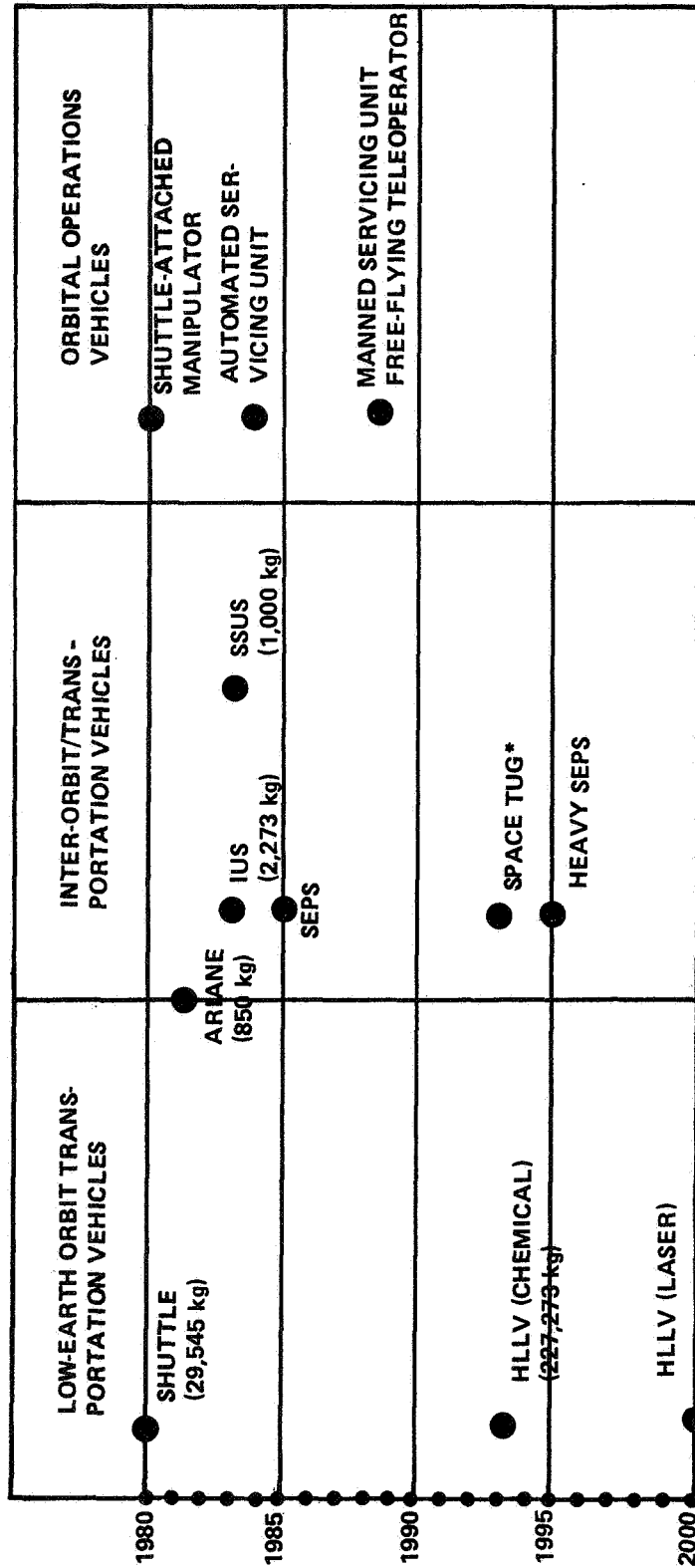
As shown in Exhibit 6-5, the launch facilities at Kennedy Space Center (KSC) and Vandenberg Air Force Base (VAFB) will be ready for Shuttle flights in mid-1979 and early 1983 respectively. Based on the current NASA traffic model, there will be a total of 545 Shuttle flights, 420 from KSC and 125 from VAFB, between 1980 and 1991. 31 possible aborts have been assumed. Roughly 23 per cent of the flights will be to near-polar orbit, which necessitates launch from VAFB to avoid overflight of land during ascent. These include important military missions and many of the survey and monitoring satellites, such as LANDSAT.

Exhibit 6-2

TRANSPORTATION SYSTEM DIAGRAM



TENTATIVE FLIGHT READINESS TIME TABLE



IUS: INTERIM UPPER STAGE
 SEPS: SOLAR ELECTRIC PROPULSION STAGE
 HLLV: HEAVY LIFT LAUNCH VEHICLE
 SSUS: SPINNING SOLID UPPER STAGE

* NASA HAS ABANDONED THE DEVELOPMENT OF THE SPACE TUG AT LEAST UNTIL THE MID 1980'S

THE PARENTHESIS INDICATES THE MAXIMUM PAYLOAD CAPACITY

Exhibit 6-4

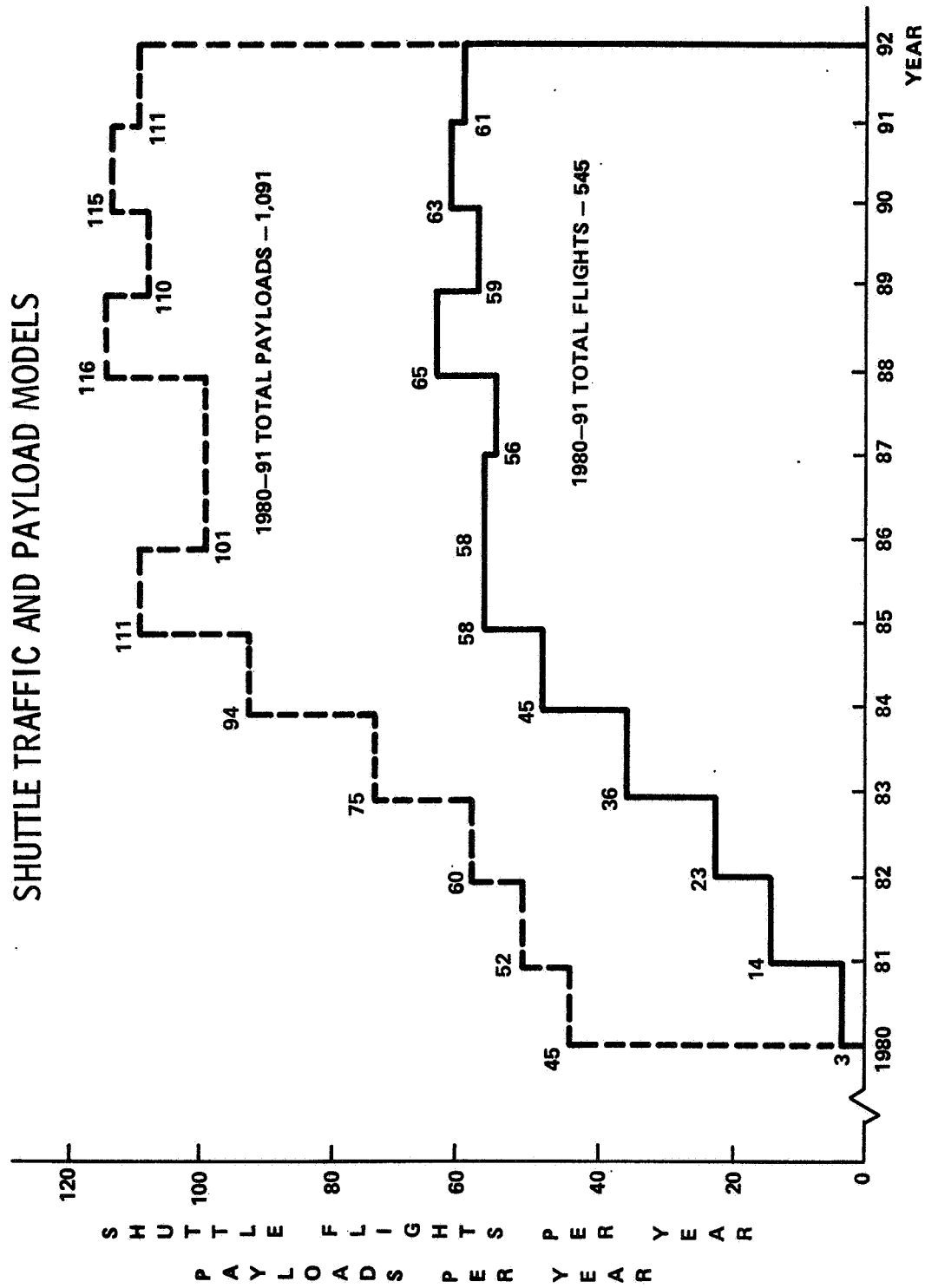


Exhibit 6-5

LAUNCH FACILITIES MILESTONES

1978	1979	1980	1981	1982	1983	
------	------	------	------	------	------	--

FIRST KSC FLIGHT

KSC	CONSTRUCTION	OFT*	ORBITAL OPERATIONS
-----	--------------	------	--------------------

* ORBITAL FLIGHT TEST

FIRST POLAR FLIGHT

VAFB	DESIGN	CONSTRUCTION	ORBITAL OPERATIONS
------	--------	--------------	--------------------

NASA has devoted considerable effort to identifying a series of payloads for Shuttle flights. According to the current NASA payload model, as shown in Exhibit 6-4, there will be 1,091 payloads to be flown on 545 Shuttle flights during the period 1980-91.

During the early 1980's, many payloads originally designed for expendable launch vehicles will be flown on the Shuttle. Thus, during this transition period, payload designs will be modified to fit either the Shuttle or the expendable launch vehicles.

For the user, payload integration can be characterized as a key element and there are four levels of operation in which payloads are involved before launch. These levels are:

- ° Level 4 - equipment and hardware are debugged and assembled into individual racks or pallets.
- ° Level 3 - racks are assembled onto a platform.
- ° Level 2 - racks are inserted into Spacelab and racks are joined.
- ° Level 1 - Spacelab and racks are inserted into cargo bay.

The Shuttle payload flow chart is shown in Exhibit 6-6.

The Spacelab-Payload will have been completely checked out and ready for flight prior to installation, with the exception of hazardous payload servicing to be performed during launch pad operations. After installation, only the interface between Orbiter and the Spacelab will be verified; however, monitoring of any potentially hazardous conditions will continue.

6.2.3 TRANSPORTATION TO LOW EARTH ORBIT

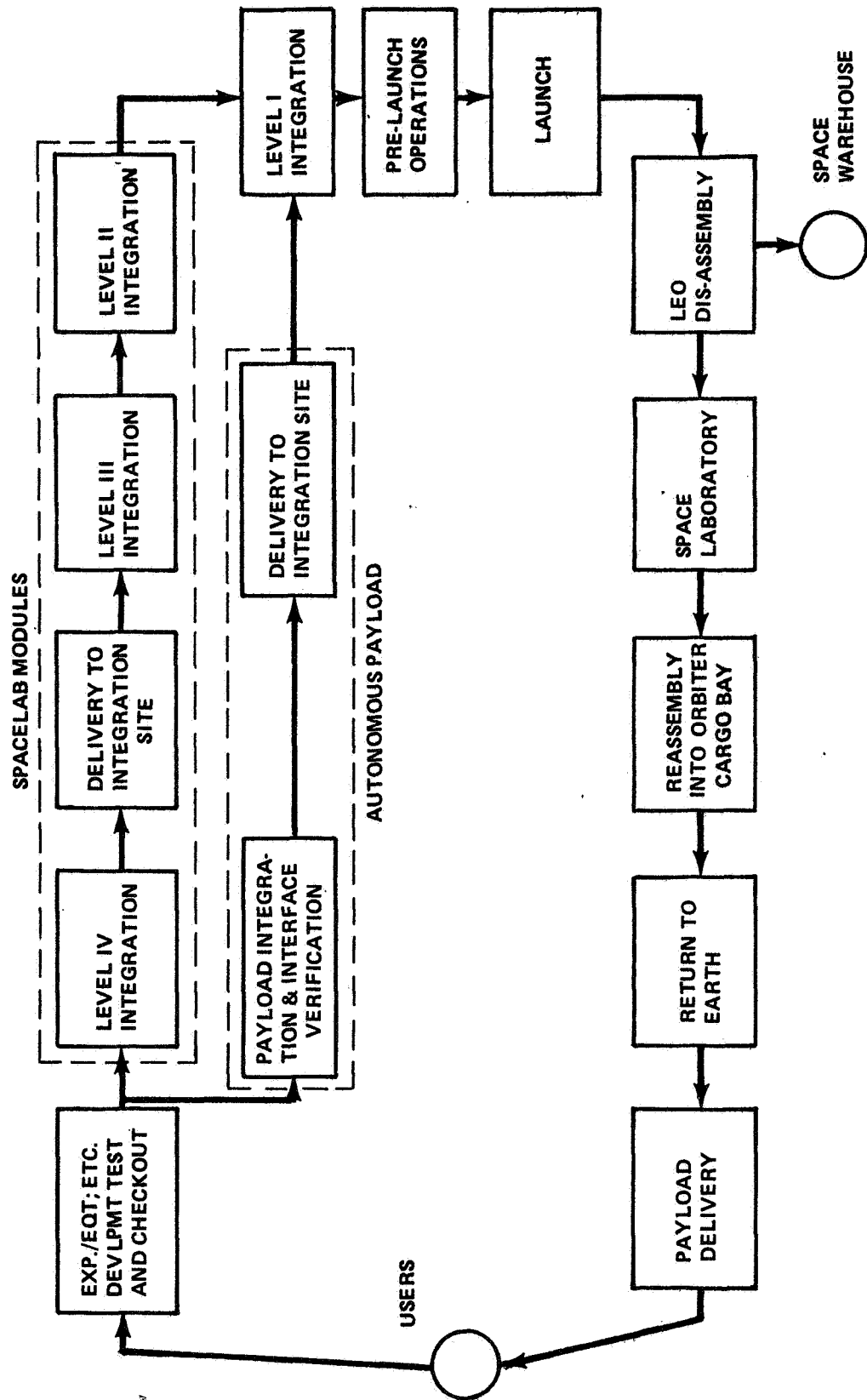
6.2.3.1 SPACE SHUTTLE

The Space Shuttle, the major component in NASA's Space Transportation System (STS) of the next decade, is designed to provide a significantly reduced cost of launching payloads up to 29,545 kg into LEO and to increase the effectiveness of using space for Earth resources, environmental assessment, etc. The Shuttle's reuseability and versatility to service and repair payloads in orbit; retrieve payloads and return them to Earth for reuse; perform critical on-orbit development testing, as well as to serve as a manned space laboratory will open the door to economical and routine operations in space.

As the Shuttle becomes fully operational, the use of expendable launch vehicles will be phased out and the Shuttle-Spacelab combination will provide the principal support for space research and operations.

Exhibit 6-6

SHUTTLE PAYLOAD FLOW CHART



A significant advance in earth-orbit transportation will develop and hopefully, a firm technology will emerge for building future advanced systems.

6.2.3.2 HEAVY LIFT LAUNCH VEHICLE (HLLV)

Logically, the Shuttle system with its 3,136 metric ton thrust provided by solid rockets and a LOX-hydrogen propulsion system is used as a basis for considering the evolution of new heavy lift systems. Boeing conducted an extensive study of the configuration, performance and programmatic requirements of a series of STS derived heavy lift launch vehicles. The six HLLV candidates selected by Boeing for evaluation are shown in Exhibit 6-7. The single vehicle selected for Class I is a minimum modification of the current Shuttle. The next two vehicles in Class II are the Shuttle growth vehicles which are adaptable to HLLV function. The last two vehicles in Class IV are the single stage to orbit ballistic entry vehicle and the two stage vehicle in which both stages reenter ballistically [Boeing - 76].

6.2.3.3 EUROPEAN AEROSPACE TRANSPORTER

For many years, especially during the 1960's when the U. S. was fully committed to large expendable launch vehicles for lunar missions, European engineers and scientists have conceived the idea of a small reusable airplane-like vehicle as a timely and sensible way for Europe to catch up with the superpowers in space technology and to drastically reduce the space transportation costs. The European Aerospace Transporter, later renamed as Small Shuttle in deference to NASA, is conceived as a small vehicle capable of launching payloads up to approximately one-tenth of Shuttle's maximum payload capability [Ashford - 75].

Unfortunately, the idea has never been developed beyond the feasibility study stage. Due to the obvious lack of Apollo environment and to the basic commitment by U. S. and Europe to Shuttle, Ariane and Spacelab at the present moment, the prospect of funding further research and development in the near future appears to be dim. The idea is too attractive to be shelved. A long-term project should be planned in view of Small Shuttle's potential advantages. The advantages are:

- ° The reduction of the costs of launching small payloads, such as small satellites, and those of operating Spacelab
- ° The ability to carry out rescue and various military missions
- ° The capability of acting as a small manned observatory
- ° The servicing of large satellites
- ° The greater freedom of orbit and launch time, and shorter lead time

Exhibit 6-7

HLLV CANDIDATES

PAYLOAD CLASS (METRIC TONS)	ACTIVITY LEVEL (METRIC TONS/YEAR)					
	500	2500	5000	25000	125000	
60-90	7	34	67	334	1667	
90-135	5	23	45	223	1111	
135-208	3	15	20	100	747	
200-300	X	10	20	100	500	
300-500	X	X	14	67	333	

CLASS 1

2 X SRB/ET/CAPSULE



CLASS 2

4 X SRB /ET/CAPSULE



BALLISTIC/ET/CAPSULE

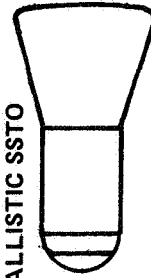


WINGED/ET/CAPSULE

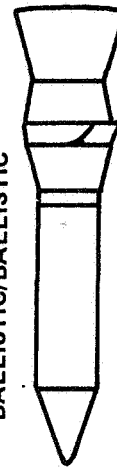


CLASS 4

BALLISTIC SSTO



BALLISTIC/BALLISTIC



THIS EXHIBIT IS REPRODUCED FROM SYSTEMS CONCEPTS FOR STS-DERIVED HLLV STUDY BOEING AEROSPACE CO. NAS9-14710

- The ability to ferry crews, expendables, experimental equipment for materials processing, Earth resources survey, etc.
- The ability to service Spacelab for extended duration on-orbit operations.

6.2.3.4 ARIANE

Ariane, Europe's new launcher, was developed by a combined effort of ten European countries under French leadership. The test launches for Ariane are planned to take place between June 1979 and October 1980 at Kourou (French Guiana), and the first operational launch is scheduled for December 1980.

Ariane possesses the capability of launching a variety of payloads ranging from 350 to 850 kg into a 185 km orbit and into a geostationary transfer orbit. It is also capable of taking payloads of roughly 400 kg on a trajectory away from the Earth. On the basis of ESA's market studies, it could be used as a launcher for 30 to 50 Earth satellites in the 1980's. That is equivalent to the estimated requirement for European communications, navigation, and meteorological satellites [Bartusch - 77].

The ten countries that participate in the European launcher program under French leadership are France, Germany, Belgium, the United Kingdom, the Netherlands, Spain, Italy, Sweden, Denmark and Switzerland.

6.2.4 TRANSPORTATION TO HIGH EARTH ORBITS

6.2.4.1 INTERIM UPPER STAGE (IUS)

NASA once considered the development of an upper stage, but it was later decided that DoD take the responsibility for the development. The upper stage was named the Interim Upper Stage because NASA at that time still had plans to develop a reusable space tug, which would later replace the IUS. Due to budgetary constraints, NASA had to abandon the development of the space tug at least until the mid-1980's.

As presently planned, IUS will be developed with the capability of delivering, but not retrieving, payloads up to 2,273 kg from the low to high Earth orbits, principally the geosynchronous orbit. It comprises two expendable stages, each propelled by a solid-propellant motor. The Shuttle/IUS delivers greater payload to geosynchronous orbit than does either the Delta or Atlas-Centaur launch systems, but it and its payload take up at least half the Shuttle capacity.

DoD plans to integrate the IUS with the Titan III as a short-term, transitional backup to the Shuttle. However, the primary goal is to use it with the Shuttle.

6.2.4.2 SPINNING SOLID UPPER STAGE (SSUS)

The SSUS is designed to deliver payloads of 568 to 1,023 kg in a spin-stabilized mode from the Shuttle Orbiter in LEO into high earth orbits. It is being developed by the industry at their expense. To keep development and unit costs low, SSUS uses solid-propellant motors and requires no costly guidance systems.

The SSUS is an economical concept. It will simply be spun up, deployed from the Shuttle, and then fired into the desired orbit.

The IUS and SSUS are being configured to be used on the expendable launch vehicles as well as the Shuttle.

6.2.4.3 ORBITAL TRANSFER VEHICLE (OTV)

The OTV is a class of vehicles under study as the next generation of upper stages beyond the IUS and SSUS systems. The OTV under consideration will use chemical and solar electric propulsions.

To provide for missions at high earth orbits in the future, the Shuttle-IUS/tug concept of the present Space Transportation System should be extended, since it is mass efficient and cost effective to use separate vehicles. Except for personnel and high-priority cargo transportation, the transfer from low to high earth orbits need not be fast, so that a larger capacity vehicle could use mass efficient and low thrust propulsion.

There are two basic cargo orbital transfer vehicle (COTV) systems distinguished by whether the payload-supplied power for LEO-to-GEO propulsion is available or not. Both systems are used to transport only material (not personnel) for space construction. In the case when the power is not available from the payload, the COTV needs to supply its own energy. Even though it is still possible to use electrical propulsion for orbital transfer in this case, it requires a heavy dedicated power source. Under this condition, chemical, nuclear, laser and other propulsion systems become very competitive.

A conventional chemical rocket, instead of electrical propulsion, is being incorporated into a Personnel Orbital Transfer Vehicle to rapidly transport personnel and high-priority cargo, sensitive to radiation effects, through the Van Allen radiation belts.

6.2.5 PRIVATE VENTURES IN SPACE TRANSPORTATION SYSTEM

The difficult funding situation in the European Aerospace Transporter signifies and typifies the real need for active participation of the private sector in the exploitation and exploration of space. It is essential that the development of an efficient space transportation system is not hindered by bureaucratic difficulties and unnecessary legal constraints. Future planning must allow for private ventures to be possible, even though the probability of such a venture appears to be low at

this time. Consideration must also be given to the possibility of an international, privately supported launch facility, preferably near the equator. Space law should not prevent either of these situations from developing.

6.2.6 DoD'S STS ROLES IN RELATION TO NASA

DoD's roles and responsibilities for the STS are much larger than generally recognized. DoD looks upon STS as representing that next "large step for man" toward a quantum improvement in military space capabilities [Coy - 77].

Shuttle is very often thought of as a NASA program that the DoD decided to support later. It may be seen that this is not so by DoD's agreement with NASA to pay in an equitable fashion for the use of Shuttle. The agreement states that DoD will:

- Pay a fixed price of \$12.2 million per launch in fiscal year 1975 dollars for the first six years, and for the second six-year period it will adjust the cost annually on actual costs as it reassesses them at the end of six years.
- Pay for the materials and services costs associated with Shuttle launches.
- Redesign current satellites so that they will be compatible with Shuttle configuration.
- Be responsible for the Shuttle installation at Vandenberg Air Force Base.
- Develop interim upper stages (IUS) to put satellites into the higher orbits.
- Pay for the cost associated with Kennedy preparations involving the security of classified military payloads.

In return for its commitment to Space Shuttle Program, DoD plans to use the Shuttle:

- As a testbed in the development of its spacecraft
- For launching DoD payloads into orbit, including some components or subsystems that are not necessarily operational and get some early understanding of their capabilities
- For diagnostic on-orbit servicing and for some manned space applications

DoD insists that a high degree of certainty be maintained in regard to launching payloads into orbit because of national defense responsibilities.

DoD also plans to phase out the expendable boosters and be fully committed to the Space Shuttle Program [Hearings - 77].

6.2.7 TRANSPORTATION OUTLOOK

The Space Shuttle will be available for flight in 1980 immediately following the orbital flight test program. With the advent of the Shuttle, there is easy access into and out of space; and a new era in the exploration and use of space will commence with the anticipated reduction in the cost and complexity of delivering payloads to space.

Presently, the expendable launch vehicles, such as Delta, Atlas, Centaur, and various configurations of Titan, carry the major load of U.S. launch activities. As the Shuttle becomes operational, the use of expendable launch vehicles will phase out and the Shuttle-Spacelab combination will provide the principal support for space research and operations. As requirements for on-orbit construction facilities and for longer duration in space develop, it will no longer be cost effective to return all system elements to Earth at the conclusion of each Shuttle flight. Many system elements will be left in orbit and will only be activated in a Shuttle-tended mode of operation while the Shuttle is on station. As demands grow, the limited-duration Shuttle-Spacelab missions will progress to a permanently manned station providing continuous operations, fabrication and assembly of large structures, and test activities in orbit.

The Shuttle will continue to be the primary transportation system through the early 1990's when heavy lift launch vehicles will be available for transporting into orbit large, heavy loads of materials and supplies necessary for establishing and maintaining large space structures. Throughout this period, there would be a continuing need for an expendable booster of the Titan class for some military missions.

Operations conducted with the Shuttle-Spacelab will nominally be limited to short durations, ranging from 7 to 30 days. Missions planned for the 1985-2000 time frame, dictated by this study, will require flights of longer duration. It would be cost effective and scientifically desirable to leave Spacelab in orbit for a few months or even longer. In other situations, such as for materials processing, it would also be desirable to deploy processing facilities permanently in orbit, periodically supply them with raw materials and return the products to Earth. For these and many similar missions, a European Small Shuttle, with its previously stated potential advantages over Shuttle in some operations, appears to be capable of meeting these demands. Unfortunately, due to funding difficulties, the European Small Shuttle has never been developed beyond the feasibility study stage. Ariane, Europe's new launcher, is scheduled for its first operational launch in December 1980. It will be a valuable addition to the transportation system.

It is desirable that advanced transportation vehicles be developed in the early 1990's in order to achieve the goal of economically viable industrial utilization of space in this century and towards making "man is in space to stay" a reality.

6.3 PROCESSES AND PRODUCTS

6.3.1 INTRODUCTION

Space represents a unique environment for research in product and process development. Although at present only a limited amount of research has been conducted in space, a number of promising areas have been explored. Products and processes that seem to have potential at this time are considered in this section.

The successs of materials processing experiments on Skylab (Appendix D) [Stuhlinger - 75] and the Apollo-Soyuz Program [Froehlich - 76] was encouraging. As a result, NASA is providing the capability for public parties to conduct experiments in space (Appendix C) [NASA - 77] using the Shuttle system. Private companies are also being encouraged to consider products which might in the future be economically manufactured in space. Studies show that in many cases disparate products require similar technologies in their manufacture, e.g., fluid phenomena, phase separation, heat and mass transfer. However, it now appears that a significant period of supporting research and technology, plus adjustments in non-technical factors, such as patent rights, and number of Shuttle flights will be necessary to demonstrate a class of feasible products that will attract private investment on a large scale. The products to be manufactured should:

1. Utilize the unique properties that are obtainable in space,
2. Have far reaching effects for the benefit of mankind,
3. Have an industrial user market so that the product will be commercially profitable, and
4. Utilize as much as possible the manufacturer's in-house facilities.

Dr. Leo Steg of General Electric [Steg - 77] suggests that the products which might show the greatest promise would be those associated with weak forces, since gravity itself is a weak force. The removal of the gravitational effect would no longer interfere with the other weak forces and might result in improved or new processes leading to new or greatly improved products.

6.3.2 UNIQUE PROPERTIES OBTAINABLE IN SPACE [Siebel - 77, Waltz - 77]

- ° Low gravity (10^{-4} to 10^{-6} g) which makes possible:

Containerless processing via electromagnetic forces, acoustic positioning or electrostatic forces. Containerless processing eliminates contamination and reduces stresses during solidification. It also results in cleaner surfaces and reduces dislocations and nucleation,

The reduction or elimination of gravity-driven convection, segregation of components, and sedimentation,

The reduction of hydrostatic pressure gradients,

The elimination of self-deformation in solids, and

Permits the mixing of hitherto immiscible materials of different densities

- ° Ultra-high vacuum (10^{-12} torr to be available at present in the wake shield) and high pumping speed
- ° Unlimited solar energy
- ° Infinite heat sink
- ° Infinite volume
- ° Low noise and potentially low vibration

6.3.3 PROCESS RESEARCH

This section is divided in two parts -- scientific process research and industrial process research.

6.3.3.1 SCIENTIFIC PROCESS RESEARCH

The scientific processes which will most likely receive attention are listed below [Outlook - 76; Wachtman - 77; Waltz - 77]:

° Chemical/Fluid

Surface tension driven convection phenomena
 Droplet coalescence studies
 Bubble nucleation studies
 Thermal diffusion controlled separation studies
 Multiphase fluid phenomena
 Flocculation studies in polymers
 Emulsion polymerization phenomena
 Electrolysis reaction studies
 Particulate generation from chemical reactions
 Solution crystallization studies

° Chemical

Improved combustion safety standards
 Flame chemistry (behavior of flame front in lean combustion, chemical and mass transport involved)
 Composites
 Chemical transport

Catalytic chemistry
 Electrochemical deposition
 Electrolysis
 Formation of thin films with or without surfactants
 Foam formation and stability

° Biological

Dialysis
 Electrophoretic separation of cells, serums, proteins
 Growth of bacterial cultures
 Lyophilization
 Isotachophoretic separation of biological material
 Growth of biological cells in low-g

° Fluids

Vaporization and condensation
 Fluid dynamics and diffusion
 Heat conduction
 Transport properties (Benard flow)
 Combustion in fluids
 Phase transformation and thermodynamics
 Rate-sensitive reactions dominated by convective mass transport
 Critical point phenomena
 Surface tension
 Thermophysical property measurements
 Bubble regimes and bubble fining in molten viscous fluids
 Fluid surface dynamics
 Non-gravity mechanisms and convections
 Aerosol mechanisms
 Capillary mechanisms
 Surface waves
 Gas jets
 Stability of fluid jets
 Interfacial kinetics
 Liquid dispersion
 Vapor deposition
 Limiting convection phenomena
 Equilibrium shapes and stability of rotating liquid masses
 Understanding of drop fusion and fission
 Behavior of strongly oscillating liquid drops
 Liquid phase sintering
 Effect of gravity on the critical point of fluids
 Behavior of fluids (particularly superfluids) at consolute points

° Metals

Sintering
 Solidification (changes in convective flow)
 Alloys

Foams
 Magnetostriction
 Controlled solidification, unidirectional solidification
 Amorphous ferromagnetic materials
 Magnetic materials
 Coating and refining by evaporation and condensation
 Electrolytic refining
 High purity metals
 Melting and freezing by levitation
 Ductility
 Intermetallics

° Electronic Materials, Ceramics and Glasses

Glasses for infrared transmission
 Phase transformation
 Formation of new glasses (complex glass formation)
 Bubble removal in glass (Marangoni flow)
 Heterogeneous nucleation in glasses, homogeneous
 nucleation in glasses
 Directional solidification of ceramic compositions
 Crystal growth by chemical vapor transport
 Crystal growth (homogeneous nucleation)
 Composites (superconductors, lubricants)
 Bridgman crystal growth
 Flux crystal growth
 Liquid phase sintering
 Controlled solidification
 Molten zones in microgravity
 Containerless shaping of lenses
 Preparation of oxide-free glasses
 Crystal growth from melts
 Contamination free complex glasses
 Zone refining
 Czochralski crystal growth
 Coating by evaporation and condensation
 Polarization
 New and improved semiconductors
 Optical fibers
 Pure semiconductors

6.3.3.2 INDUSTRIAL PROCESS RESEARCH

The industrial processes which will likely receive attention are listed below [Wuenschel - 72; Stine - 75]:

° Free and Captive Suspension

Crucible support, wetting and nonwetting
 Sting support
 Electromagnetic or electrostatic
 Acoustic levitation

◦ Mixing

Mechanical
Induction

◦ Separation/Purification

Centrifugal separation, free or container
Velocity separation, condensation or selective membrane
Electrophoresis
Magnetic separation (mass spectrometer)
High-vacuum refinement, centrifugal or Marangoni

◦ Alloying and Supersaturation

Premixed powder melting
Thermosetting or diffusion alloying

◦ Casting

Surface tension casting and free casting
Supersaturated alloy casting
Composite casting, 2-state or 3-state
Adhesion or layer casting

◦ Liquid State Forming

Blowing
Electrostatic field forming
Composite casting, 2-state or 3-state

◦ Controlled Density Processing

Dispersion foaming
Vaporization foaming
Variable density casting

◦ Deposition

Adhesion coating
Galvanic plating and coating
Vapor deposition

◦ Solidification

Amorphous solidification
Controlled crystallization
Single crystal solidification
Supercooled coining

◦ Melting

Complete melting, low and high viscosity, overheated
Partial melting, matrix melting in cermets

- Vaporization
 - Fractional distillation
 - Pressure drop vaporization
 - Freeze drying
- Nuclear Processing
 - Fission breeding
 - Fusion breeding
 - Irradiation
- Chemical Progressing
 - Polymerization
 - Free radical chemistry
 - Free atom chemistry
- Fermentation

6.3.4 POTENTIAL PRODUCTS

The products listed below have been identified at present as preferred candidates for manufacture in space [McKannan -77; Carruthers - 77]. These candidates fit the criteria outlined in Section 6.4.1.

1. Glass micro-balloons for containing deuterium-tritium gas for laser fusion targets. These are of larger dimensions than can be manufactured on Earth and still meet other required specifications, such as sphericity [Carruthers - 77].
2. Latex spheres for biomedical research. They could be prepared in microgravity and used for the calibration of various instruments such as Coulter Counters for blood cell counts and could help in the study of glaucoma, rheumatoid arthritis and cancer [Vanderhoff - 76; Kornfeld - 77].
3. Infrared detectors - Mercury Cadmium-Telluride crystals [Davidson - 77].
4. Tungsten X-ray tube targets of high purity - The tungsten could be manufactured in space by levitation processing to reduce grain boundaries and interstitial impurities, particularly oxygen and carbon, for long-life X-ray tube targets [General Electric - 73; Wouch -74].
5. Purified anti-hemophiliac factor to help blood coagulate in the treatment of hemophilia.

6. Enzymes from live human cells which have been fractionated [McKannan - 77].
 - Urokinase - reliable enzyme to dissolve blood clots
 - Erythropoietin - used to stimulate the production of red blood cells in the bone marrow
 - Insulin - used by diabetics

6.3.5 PROMISING PRODUCT POSSIBILITIES

1. Beryllium Sheet - Beryllium is very difficult to handle on Earth. It is not ductile and presents many impurity problems. The Beryllium Company of North America is interested in this product. In space, the beryllium could be levitated in the form of a sphere and then melted and quickly re-frozen. (Other metals which are usually contaminated by their crucibles and which could be purified in the space environment are: titanium, niobium, zirconium, vanadium, tantalum, and molybdenum) [Wouch - 77; Downey - 77].
2. Intermetallics - Binary combinations of some metals show liquid immiscibility on Earth but demonstrate lack of sedimentation and density driven convection in space. In a strictly technical sense the materials, while not actually miscible, remain finely dispersed. The result is intimate dispersion of one element into a bulk matrix of the other material. The experimental aspects of this project are just being developed at the present time [McClure - 77; Reger - 73].
 - Superior superconductors - On the Earth when solid aluminum-bismuth is melted, the bismuth forms spheres in an aluminum matrix (under the properly controlled heating and cooling processes). In space, these bismuth spheres might possibly be formed into continuous filaments and might form a superconductor. Other metallic combinations are possible, and some of these might prove to be superior superconductors.
 - Improved control rods for nuclear reactors (Cd-Pu Combination).
 - Solid lubricants (C-Cd, ductile graphite).
 - Stronger alloys (resistance to deformation) - Add a harder material to a softer one, such as thorium dispersed nickel.

- New semiconductor materials from supersaturated alloys of gallium-bismuth, lead-tin-telluride.
- Magnetostrictive and polarizing applications.

3. Optical Glasses

- Glasses of (As-S), (Si-As-Te-Sb) show promise for infrared transmission [Downey - 77].
- Glasses of high purity and homogeneity - highly purified glass for lasers and laser system optics, low-loss fiber optic transmission lines [Waltz - 77].
- Oxides of lanthanum (La_2O_3), tantalum (Ta_2O_5), aluminum (Al_2O_3) and yttrium (Y_2O_3) have optical properties not obtainable in conventional silicate, borate, and phosphate glasses making them suitable for laser applications and advanced optical systems. Crystal free laser glass might be obtained by increasing the calcium oxide content of glass [Grey - 77; Downey - 77].

4. Crystals

- Crystals of unlimited size and higher quality (less dislocation and nucleation). Crystals of germanium selenide, germanium telluride, indium antimonide, boron arsenide, germanium sulfide and silver have proved successful [Stuhlinger - 75].
- Larger size silicon single crystals and silicon ribbon [Grey - 77; McDonnell-Douglas - 77].

5. Other Promising Product Possibilities

- Perfectly spherical ball bearings and specially shaped objects using computer controlled fields, seamless hollow ball bearings [Dooling - 76].
- Metallic foams for battery plates, crushable structures, aircraft and spacecraft parts [Dooling - 76; Downey - 77].
- High coercive strength permanent magnets, using new high strength alloys [Geschwind - 77; Gould - 77].
- Eutectics for aircraft engines turbine blades, magneto-resistive applications, infrared polarization lenses, electronic components and ferromagnetic eutectics [Wouch - 74].

The list above is just the start of many products and process which most likely will be developed, as the result of research, in the next decade.

Appendix E outlines a space processing product evaluation, while Appendix F presents a chart outlining a schedule for suggested space processing and manufacturing [von Puttkamer - 77].

6.3.6 EXPERIMENTS FOR FIRST SPACELAB MISSION

A list of materials science experiments that the European Space Agency (ESA) intends to perform on the first Spacelab mission currently scheduled to be launched in December 1980 is given in Appendix G [Wittenstein - 77; Mullins - 77].

6.4 FACILITIES FOR MATERIALS PROCESSING IN SPACE

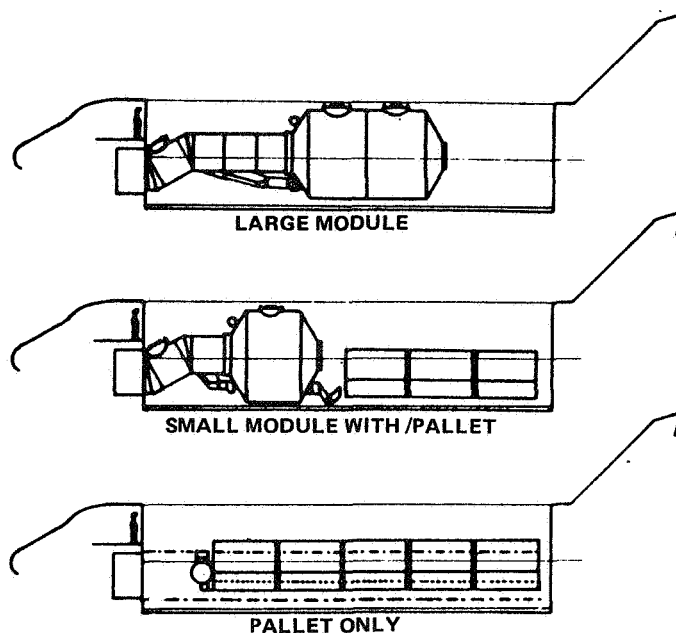
In the process of developing the space environment and in attracting commercial ventures in materials processing, the requirement for physical facilities is obvious. Such facilities must first be specified in a conceptual manner and then be engineered to exact specifications, but consideration of this sequence is complicated by two main factors. First, to date there has been no specific product or process that has proved to be highly attractive for materials processing in space from an economic point of view, although a number of promising ideas have been investigated [Edgar, Skylab - 76; Gatland - 76] as discussed in Section 6.3. Second, the engineering details of any processing facility will depend to some degree on the process, and once it is known, the engineering technology can be readily provided by NASA and the industry. Consequently, the conceptual evolution of a space manufacturing facility will be emphasized here, rather than engineering the details. The problem of facilities is investigated in this section by first summarizing the current Shuttle program, then exploring a number of practical considerations in the evolution of facilities that will be attractive to commercial firms, and finally considering some long-range facility concepts that could conceivably be developed before the year 2000.

6.4.1 THE CURRENT SHUTTLE PROGRAM

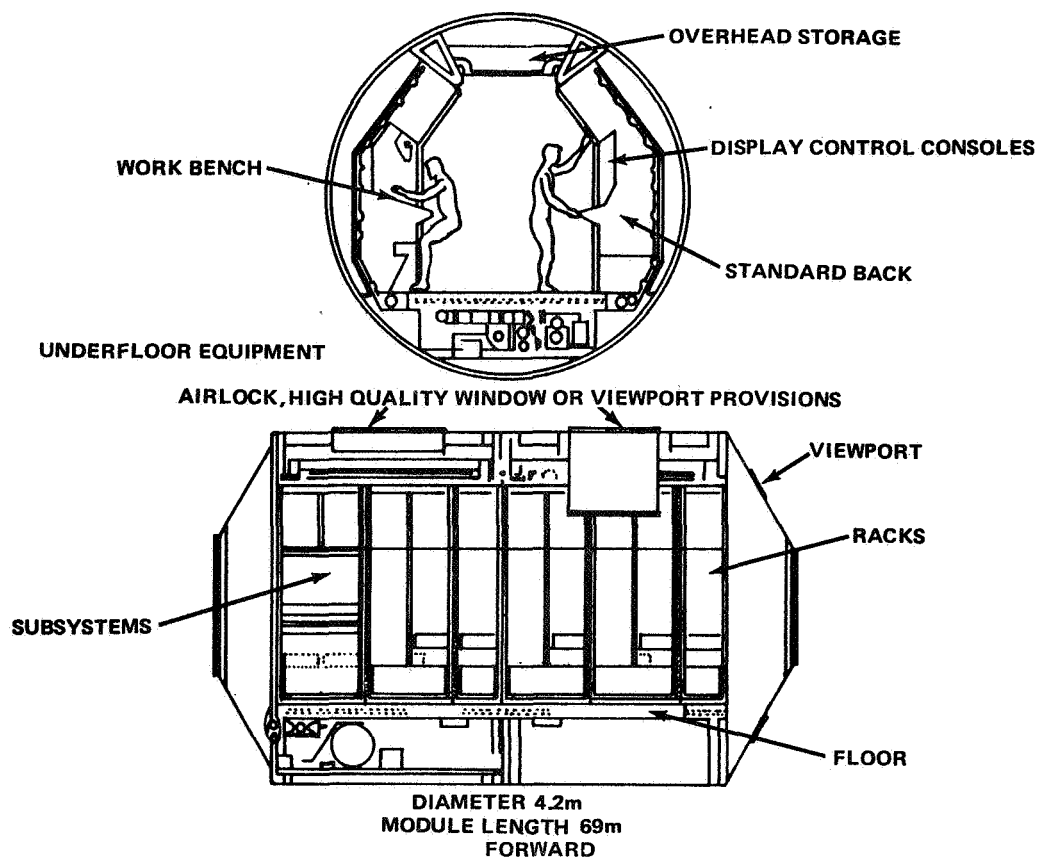
Although the concept of a reusable space vehicle has been around for many years, the necessary funding to develop the United States Shuttle program was not provided until early in 1972. By that time, Shuttle planning had gone through a series of evolutionary changes and was essentially the vehicle of today [NASA-Shuttle - 76]. It consists physically of a main Orbiter which will contain all personnel and payloads, a large external fuel tank (ET) for the orbiter's engines, and two solid-propellant rocket boosters (SRB). The Orbiter and the SRB's are designed to be recovered and reused; the ET is not recoverable, but it has been designed with the interesting feature that it can be flown into orbit if the Orbiter payload is reduced. Reuseability provides the primary advantage of the Shuttle Transportation System (STS), namely that large payloads can be placed into orbit at low cost compared to expendable rockets. The initial uses of the STS will be to launch and recover satellites primarily for military purposes, and to do basic scientific research.

SPACELAB DETAILS

THREE TYPICAL SPACE LAB FLIGHT CONFIGURATIONS IN ORBITER CARGO BAY



SPACELAB CROSS SECTIONS



This research application will take several forms, depending on the originator and on the equipment that is available from the Orbiter. For example, a large telescope will be provided by NASA as a Shuttle payload for astronomy research, and a free-flying long duration exposure facility will also be developed for studying the effects of long exposure on plants and animals in space. Both of these facilities will be extensively subsidized by the Federal Government, as will much of the other initial research effort. The most interesting and complex Orbiter payload from a materials processing viewpoint, however, is the Spacelab [Baker - 75; NASA, Spacelab - 76]. This is a highly flexible, modular scientific laboratory that is designed to be carried in the Orbiter cargo bay. It can support both manned and unmanned experimental work in a variety of disciplines, depending on the particular configuration and internal equipment selected by the users. The Spacelab consists of various combinations of long and short cylindrical pressurized modules which can provide a habitable environment, and also one or more cargo pallets that will contain experiments which are to be exposed to the space environment. Some Typical configurations are shown in Exhibit 6-8. Spacelab evolved from an early U. S. effort to develop a ten-man, free-flying space station which was abandoned in 1971 for lack of funding. The present effort is funded by a group of European countries, primarily West Germany, called the European Space Agency (ESA) [Stephens - 76]. The Spacelab will be used initially by both ESA and NASA for experimental work, with most equipment configurations based on one of several standard Spacelab kits to be provided in such areas as astronomy, physics, biology, and the life sciences [Edgar, Shuttle - 76]. NASA has agreed not to introduce an alternative space laboratory until 1985, but does have the option of buying additional Skylabs from ESA. After that date, there are no such restrictions other than anticipated funding. There are also tentative plans to modify the Spacelab for free-flight by the addition of a power module of around 25 kW, which would be developed by the U. S. Currently the Spacelab relies heavily on the Orbiter for such services as power, communications, cooling, and life support. The pressurized module is connected by a tunnel to the Orbiter for transfer of operating personnel.

Uses of Spacelab can be divided into two groups, dedicated and shared. In the former a single user will purchase an entire Shuttle flight of up to seven days duration at a cost of around \$20 million, and would then be free to fly any type of experiment desired subject only to NASA safety and security regulations. Typical customers might be U. S. Government agencies and foreign governments. In a shared flight, a number of users would share the cost and payload. This will necessitate a rather involved integration process [Jean - 77] to insure that all users are properly accommodated and that there is no operational interaction between the various experiments. There is also the problem of "sharing" the NASA Mission Specialist among all users, which will require specialized training of the crewman by each user that requires human intervention or monitoring. This problem has been considered by NASA in detail [Moore - 77] and rate structures are being developed to cover such eventualities as documentation, payload assembly and checkout, and operator training. One interesting aspect of these initial shared Shuttle flights is the proposed "Getaway Special" [Moore - 77] which NASA would rent to a volume of five cubic feet in the open cargo bay for only \$10,000, primarily to encourage small potential users such as universities and research laboratories.

A number of experiments in the materials and biological areas are proposed for Spacelab to provide data pertinent to the commercial use of the environment (see Appendix G). Under the National Aeronautics and Space Act of 1958 much of the Spacelab experimental results will be available to the public, and this could possibly serve to stir interest within the industrial sector which might eventually lead to the large capital investments required for space manufacturing. However, barring the initial discovery of some highly profitable unforeseen product, it will take a much more intense research effort to determine a class of viable products that will be attractive to any significant segment of the industry. In the next section, this "shakedown research" is considered with regard to facility evolution.

6.4.2. SPACE MANUFACTURING CONSIDERATIONS

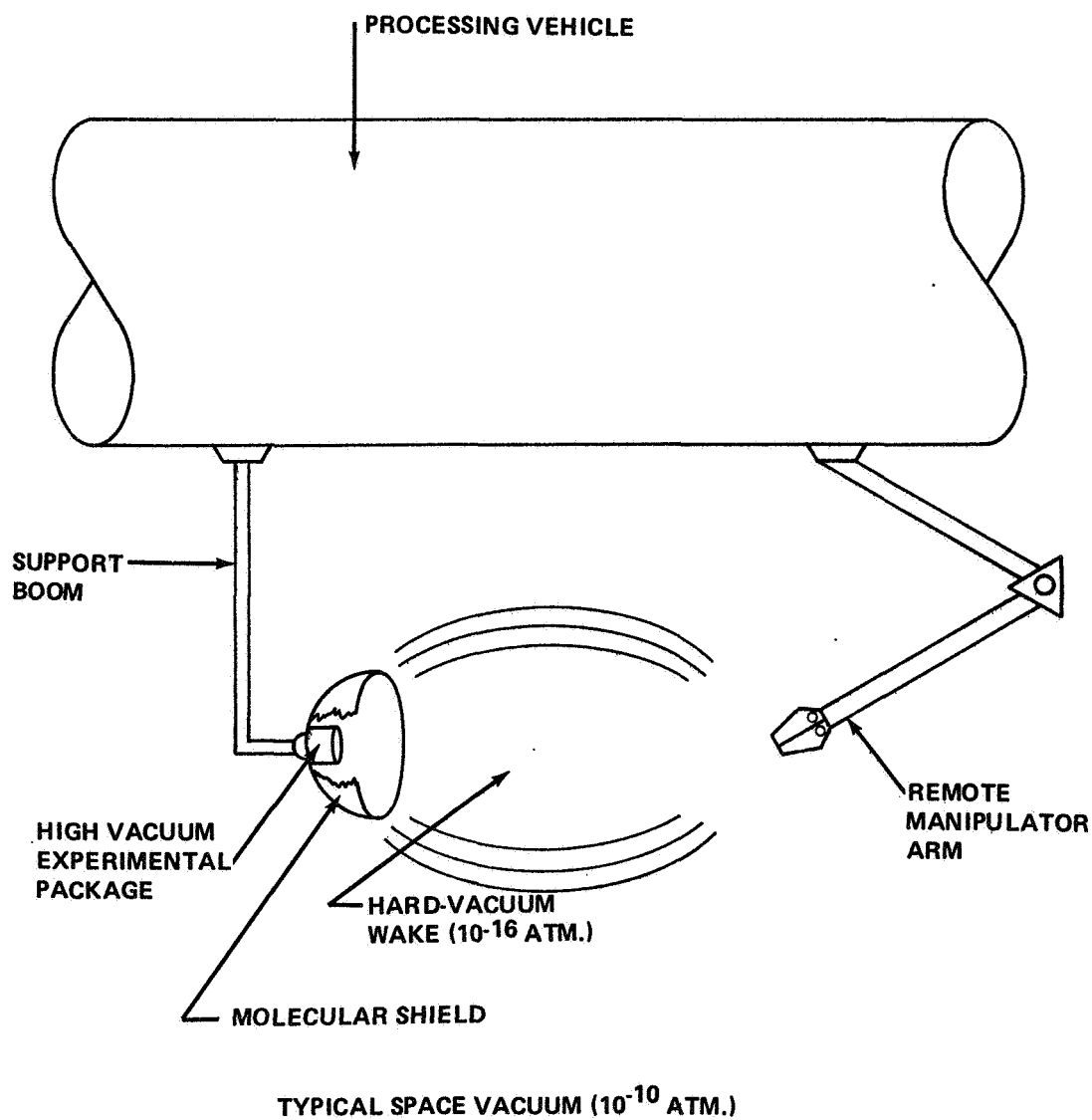
Space offers an environment for manufacturing that is unique in many ways as compared to the Earth. Perhaps the most notable characteristic is the very low gravity, or micro-gravity, which is on the order of 10^{-5} times that at the Earth's surface. Gravitational effects such as convection currents and container wall contamination are serious and often limiting in modern industrial processes, so it is quite reasonable to expect that many such processes can be significantly improved in space. In fact, the low gravity is the only property that has been investigated to any extent so far during the Skylab and Apollo-Soyuz programs. Successful experiments have been performed in the areas of crystal growth and biological cell separation. In the crystal growth experiments, it was possible to grow very large and pure semiconductor crystals due to the absence of both convection and contact with the container walls. Such crystals have potential application to electronics, and similar metal crystals could result in ultra-strong metals. The biological experiments used the absence of gravity to allow the separation of nearly similar cells by electrophoresis. The resulting products have potential application as pharmaceuticals to treat various diseases. Levitation, or containerless processing, offers a means of handling in space highly corrosive or soluble materials such as molten silicon or plutonium. Such materials can be positioned with electrostatic or acoustic fields for extended periods of time for complex processing.

A second property of space is that of high vacuum and high pumping speeds. Although the vacuum inside a space vehicle is comparable to that obtainable on Earth, much better vacuums can be obtained in space using the "molecular shield" shown in Exhibit 6-9. The shield is displaced from the vehicle to avoid outgassing contamination, and sweeps out a very hard vacuum of around 10^{-15} atmosphere. Furthermore, it does this to provide a high pumping speed since any material from the process is simply left behind in space. Most vacuum-related processes on Earth do not require such high quality vacuums, so little experimentation has yet been done in this area. However, it seems most promising, therefore, that new processes and products might be developed in space after a period of high-vacuum research.

There are several other properties of space that have not been used to any extent in experiments thus far. Since there is very little atmosphere

Exhibit 6-9

HIGH-VACUUM PROCESSING CONCEPT



at the 150-400 mile Shuttle orbit, radiation from outer space and the sun is not filtered and might be of value in some manufacturing processes. There is also a wide temperature range available, depending on whether the process is absorbing sunlight or radiating into space. A final property of possible interest is the very low vibration level than can be achieved if there is a minimum of operating machinery and sufficient damping, which might have application in the deposition of very thin layers during semiconductor device fabrication.

Another potential advantage of space is the unlimited volume available. Small amounts of waste material can be dumped directly into space, while larger quantities can be either launched into the sun, launched into deep space, or placed in a storage orbit for later use. The latter alternative has been proposed for radioactive waste, for which uses may be found in the future. Such dangerous items as nuclear products, gas warfare agents, and genetic research material can be handled in space by remote control, and in the event of an accident the entire processing module can be sacrificed with no risk to life on Earth. Finally, there is a great deal of potential security by virtue of the physical separation of orbiting facilities.

Despite the preceding advantages of space, any large-scale commercial ventures initially are considered highly unlikely for a number of reasons. Since economically attractive products have not been identified by the limited research conducted in space so far, it appears that a period of shakedown research will be essential to demonstrate viable products of interest to industry. This will probably involve considerable basic research over at least five years, and industry does not seem willing at this time to make such a commitment to an unproven technology at the level of risk involved. Furthermore, there is a basic distrust of government by industry with regard to proprietary rights and patents, taxes, and security. All of these factors indicate that it will be desirable for the government to subsidize the initial phases of space manufacturing, including both research and facilities. This includes demonstrating viable products and processes, and also providing a suitable physical and legal environment to encourage applied research and pilot-plant phase to justify full scale production, then the industry should gradually assume the full cost of both the facility and transportation.

6.4.3 EVOLUTION OF SPACE MANUFACTURING FACILITIES

Much of the initial research work can be done at moderate cost on the Spacelab where there will be extensive equipment and a trained human operator available, but it will eventually be desirable to have a dedicated free-flyer for space manufacturing development. This will allow longer exposure time than the one month limit of the Shuttle and can greatly reduce the expense. This cost reduction could be affected in two ways. First, the free-flyer could be highly automated with human intervention provided only when needed for unusual circumstances. This would avoid the high cost of life support systems and safety provisions for human operators, and allow the industrial user to concentrate his

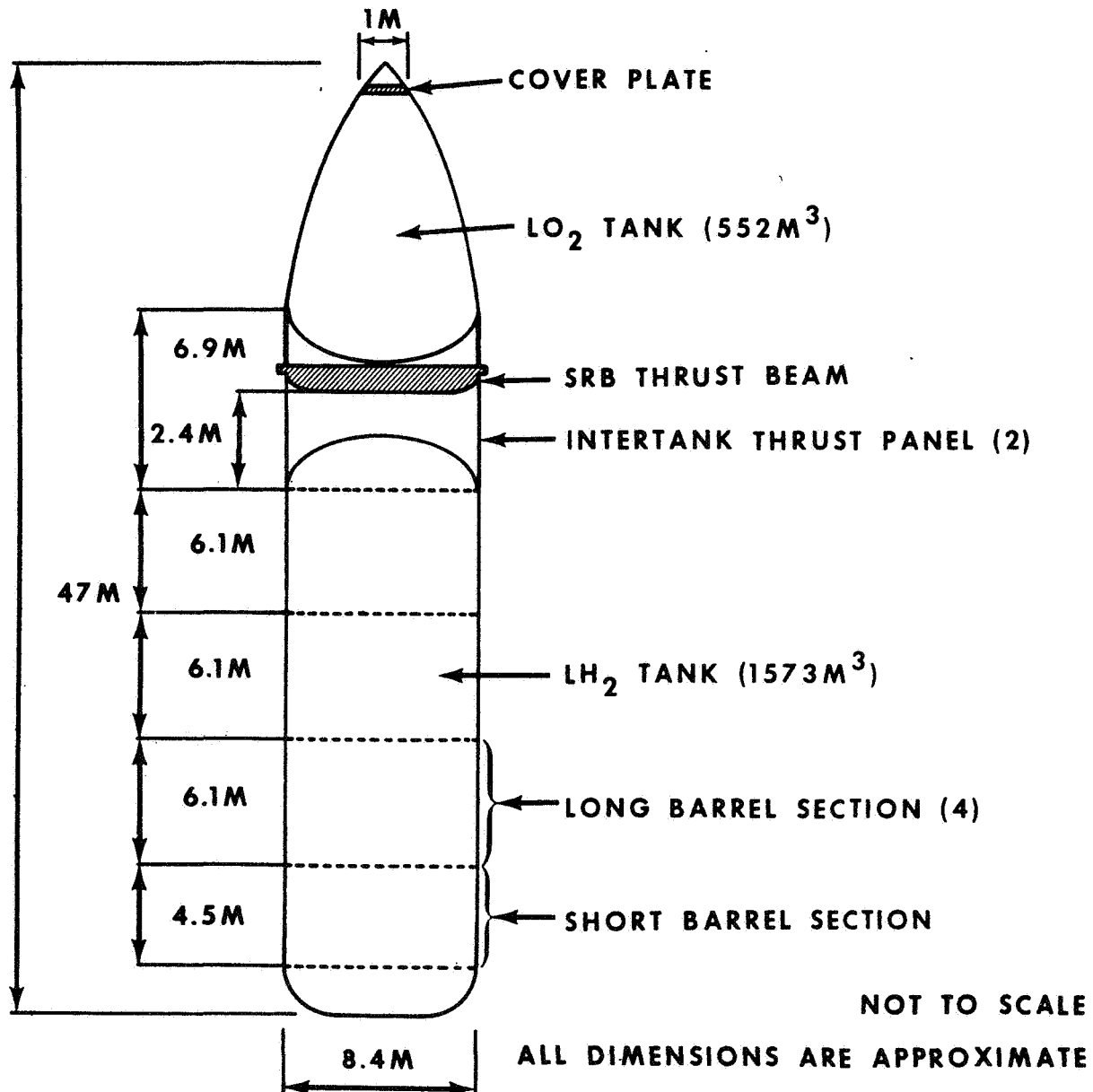
capital on the process equipment. The second cost reduction factor would result from the use of processing modules that would be owned or leased solely by the user, thus allowing permanent installation of the equipment to be used in the process development. A second advantage of a free-flying facility is security. The user's module could be out-fitted and ground-tested thoroughly in complete privacy, either at the NASA launch facility or perhaps even at the user's own laboratory. Once ready to fly, it could be sealed and scheduled for the next available Shuttle, then docked to the free-flying facility with a minimum of interference with internal equipment. Of course, the return operation could be handled similarly, with the sealed module being delivered by NASA to the user.

The question of automated vs. manned space facilities is not new. In the past, high degrees of mission operational uncertainty and a relatively unsophisticated level of development in automation has made the manned decision fully justified. However, by the time that free-flying facilities become available space operations should be very routine and reliable, and the disciplines of artificial intelligence, industrial robotics, and process control should make highly automated manufacturing plants cost effective compared with manned plants in space [Holden - 76; Nitzan - 76]. This type of automated plant would be run by a specialized computer monitored from Earth to allow intervention by remote control if necessary. An encrypted secure telemetry link would be provided by NASA via a relay satellite to allow for continuous communication between the user on Earth and his plant in space. In the event of a malfunction of the processing equipment, a decision could be made as to whether to attempt repairs from the Shuttle or to return the module to Earth. A number of support equipments would be necessary, such as power source, a communications unit and antennas, a heat radiator, and an attitude control system. The total expense of these units would be prohibitive for the individual user, but they could be furnished by NASA and shared among several users to minimize the cost per user. One example of such a facility will now be developed.

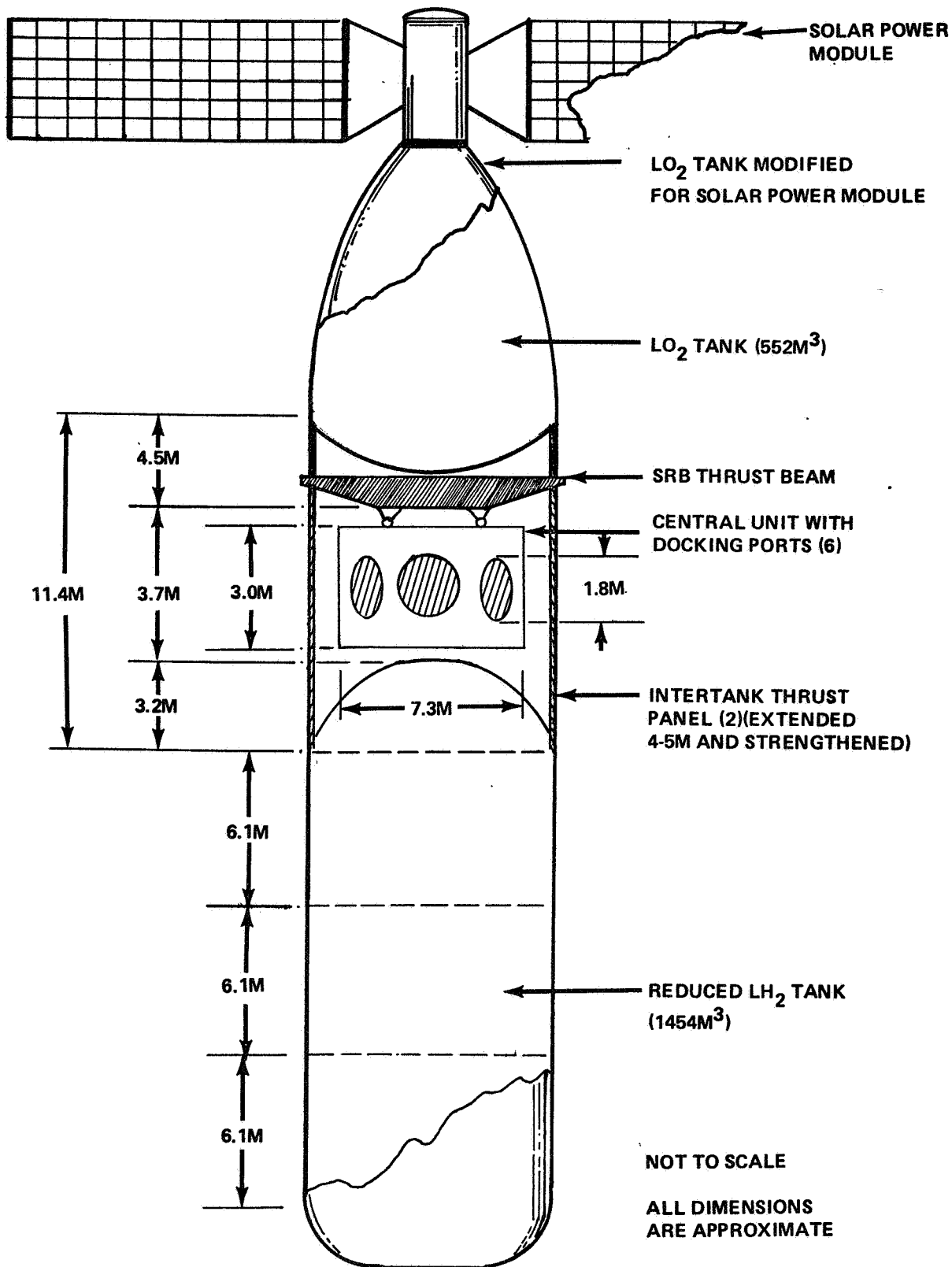
The physical facility provided by NASA for the purpose of encouraging the commercial development of space manufacturing should be as inexpensive as possible on one hand, and on the other, it should be sophisticated and secure enough to accommodate modern industrial production plants. It must also be flexible enough to provide for the evolution from small research units to larger pilot plants and eventually to full-scale manufacturing plants. Facilities for space manufacturing have previously been proposed [Geschwind -77; Daros -77], however, the one to be proposed here offers both low cost and high flexibility.

The facility design concept presented here is based on a modified version of the STS external tank (MET) that could be flown into orbit on a Shuttle flight having a reduced payload. ET design details are found in the contractor's System Design Handbook [Martin Marietta - 75]. The ET modification consists of first removing the short 453.4 meters (14.9') barrel section of the liquid hydrogen (LH₂) tank shown in Exhibit 6-10, thereby shortening this tank and reducing the Shuttle payload capacity. It is also necessary to extend and strengthen the two intertank thrust pannels, as indicated by Exhibit 6-11, and to insert a MET central unit

Exhibit 6-10

EXTERNAL TANK

MODIFIED EXTERNAL TANK (MET)



(METCU) between the SRB thrust beam and the top of the LH₂ tank as shown. The nose cover plate of the liquid oxygen (LO₂) tank is also modified with fittings and cabling for attaching a solar power unit. This modification will cause some shift in the tank center of gravity, but it can be balanced with suitable ballast in the nose. Some minor rerouting of the fuel lines and electrical cable trays may also be required, and the forward Orbiter connection point will also need reinforcing. The six remaining intertank skin/stringer panels are modified so as to be removable after reaching orbit, which exposes the METCU sides except for the two 45° arcs covered by the two remaining intertank thrust panels as shown in Exhibit 6-12.

The METCU will provide the interface between the MET support facility and the individual manufacturing modules. Once the MET is in orbit, the six removable intertank panels are released and swung back towards the LH₂ tank to expose their inner surfaces. These surfaces contain heat radiators which connect to the METCU. This operation also exposes the six METCU docking ports located on 45° arcs corresponding to the heat radiator panels. There are no ports under the two nonremovable thrust panels. Antennas for the telemetry systems are also deployed from the intertank region. Internally the METCU contains the radio transmitters and receivers, the attitude control system, power regulation and distribution equipment, and a powerful programmable computer for use in remote process monitoring and control.

The complete processing facility could be put into operation with no more than two STS flights. The first flight would carry the MET into orbit, actuate the attitude control system, and fold the heat radiator panels back. The same flight, or perhaps a second one, would carry the solar power unit and the first processing module. Once the MET is operational the Orbiter crew would attach the power unit, activate it, and check out all METCU internal functions. When proper operation is assured, the manufacturing module would be docked to one port using the Orbiter remote manipulator arms, and all initial tests prescribed by the user would be performed by the Orbiter crew. If all conditions are found normal, then the processing could either be initiated from the Orbiter or by the user via remote control. Abnormal conditions in the user's module could be handled by backloading the module on the Orbiter and performing the repairs in space, or by returning the module to Earth. Initial repairs to the METCU might be done by EVA, or perhaps by docking the Shuttle to the METCU, pressurizing it, and then sending the repairman in through the Orbiter access tunnel. The general concept of the MET facility is illustrated in Exhibit 6-13.

After the MET facility is placed in operation, the user modules will probably be oriented toward applied research and basic process development. However, as the process sophistication increases there may be periods in the development during which a human operator is desirable. The MET concept can be easily expanded to provide for this eventuality by use of a habitability module. Such a module would be transported by the Shuttle to the MET facility and docked. The module would then pressurize the METCU and any necessary manufacturing modules, thus allowing a shirt-sleeve environment for the operator. The habitability

Exhibit 6-12

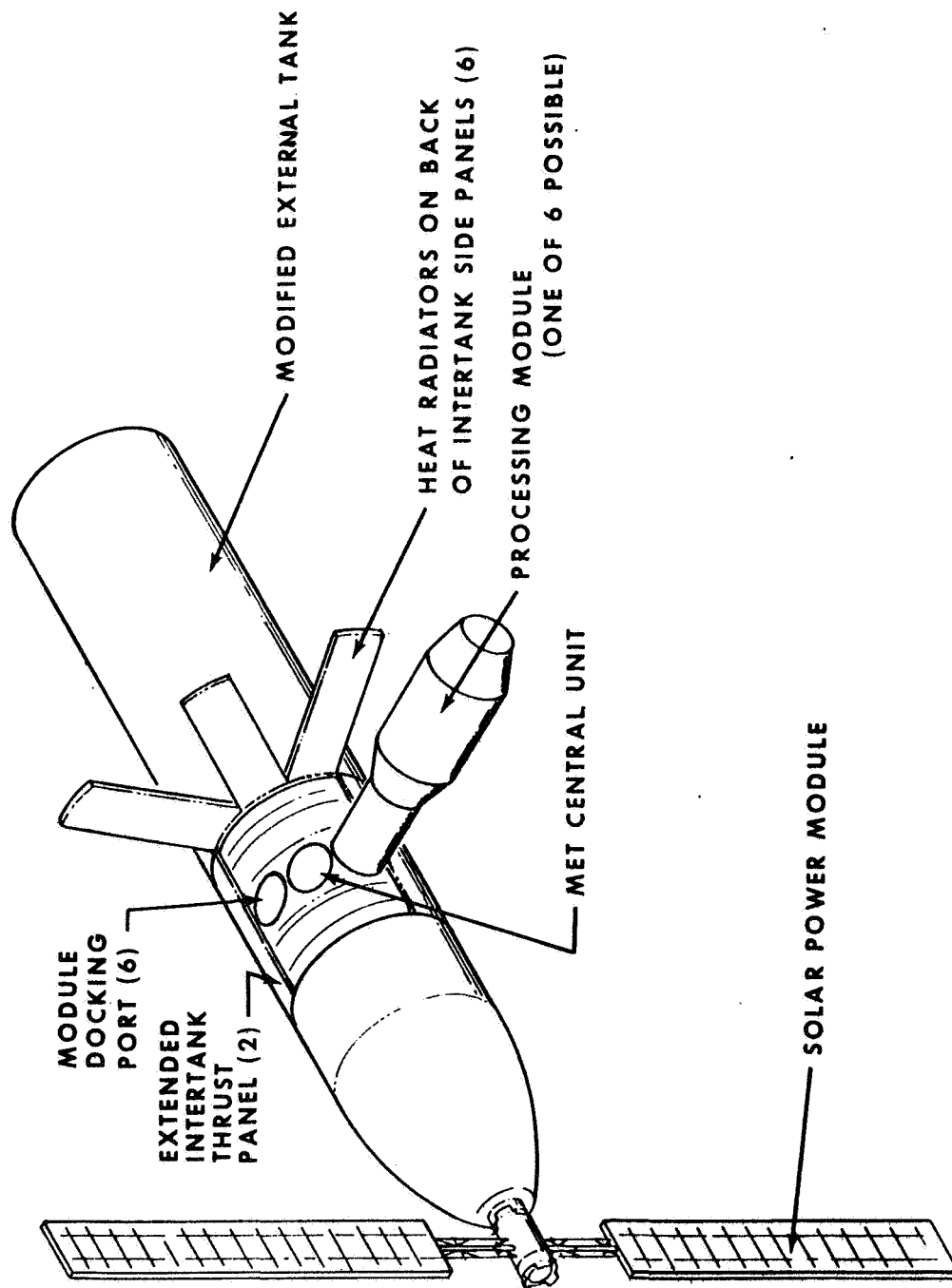
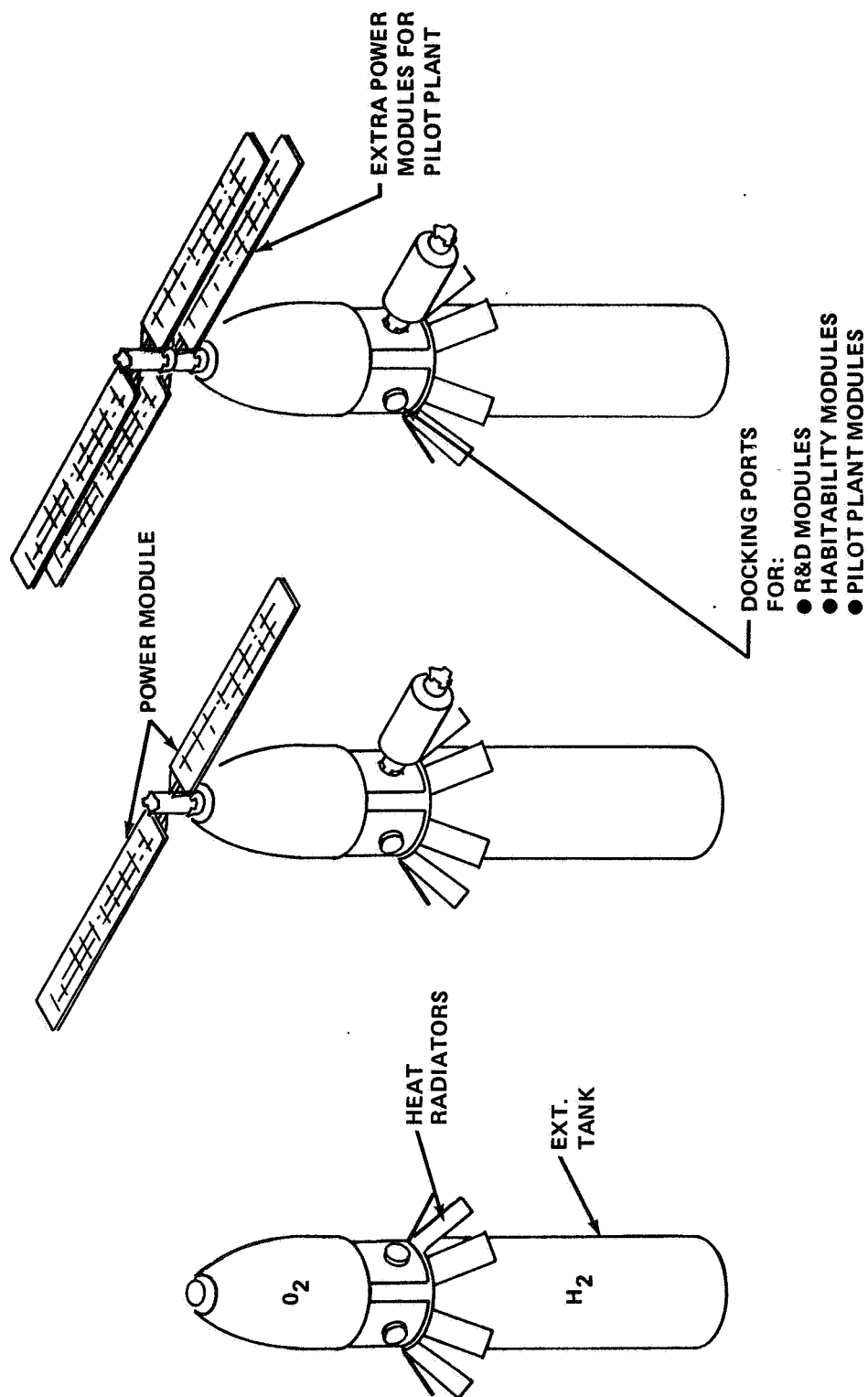
MET PROCESSING FACILITY CONCEPT

Exhibit 6-13

MET FACILITY DEVELOPMENT (INITIAL CONCEPT)



module would of course contain the life-support equipment. Operators could be resupplied from the Orbiter or by returning the entire module to Earth for refurbishing. Other modules could be used to transport raw materials and finished products.

The MET concept offers a number of advantages for developing space manufacturing. First, using the external tank provides a large, strong supporting structure with two large storage areas (the LH₂ and LO₂ tanks) for waste or raw material storage. Second, by locating the METCU at the intertank area the overall center of mass will be very close to the work areas of the manufacturing modules. This is an important requirement for levitation work, since unconstrained objects in different orbits will experience a continuous displacement relative to their centers of gravity. Third, the physical separation of about 18 meters (60') between the METCU and the solar array reduces the chance of accidental damage when docking and undocking modules with the Orbiter. Fourth, development costs are mitigated by use of existing ET structural members, hardware, and wiring, with only a few major modifications. Finally, the large METCU diameter of about eight meters (24') will provide room for both additional support equipment and, if necessary, habitability and life support facilities.

The modular concept suggested would allow the user to have a high degree of autonomy as to his particular process, but would also be more expensive than necessary if security was not essential. Initial research could be facilitated by NASA by providing a selection of modules that would be permanently outfitted with the fundamental equipment for selected areas of investigation. At the present time, feasible areas might include containerless processing biological processing, and high vacuum work. These modules could be used by small investigators such as universities and private research laboratories, as well as by major industries and governments. NASA assistance could be made available for such specialized jobs as automation, software development, and equipment details. An example of such a modular unit for biological processing is discussed in Appendix H.

If highly profitable products are discovered, it is quite possible that facilities will be required that are larger than can be transported on the Shuttle. One solution is to combine the Shuttle-transportable modules to obtain longer units of the same diameter. A second possibility is to transport larger diameter units on the Shuttle piecemeal, and assemble the pieces in space. This alternative would require specially trained workers and would consequently be rather expensive. A third alternative of transporting a large facility intact would be feasible if transportation systems became available with significantly greater lifting capacity than the Shuttle. Proposals for such vehicles have been considered, and are discussed in Section 6.2. There are two basic approaches to advanced transportation, namely, either an upgrading of the STS system or the development of an independent heavy-lift vehicle. The latter system might be relatively expensive; but could be motivated by such developments as a pressing need for solar power stations, requirements for a military command post in orbit, a national decision to colonize or mine the Moon, the development of a Russian space station, or perhaps the necessity of a large space station to alleviate a future population crisis. If such a system were developed and made available to commercial

customers, then the deployment of a large manufacturing facility would be straight-forward. On the other hand, in the absence of such high funding motivators it would still be possible to develop a heavy-lift transportation system by upgrading the power and cargo capability of the present Shuttle system. This possibility has been studied [Page - 77] and several variations have been proposed.

The Shuttle-derived heavy-lift variation considered for the MET evolution is obtained by retaining the modified external tank and upgrading the thrust of the two rocket boosters. The Orbiter vehicle would be replaced with an unmanned unit consisting of a set of Shuttle rocket engines attached to a central section that is essentially the complete factory. An aerodynamic nose cone would be mounted on top of the factory section, and the entire unit would be launched and recovered in a manner similar to the STS system. Once in orbit the rocket engines would be recovered by a conventional Orbiter and the nose cone discarded. The factory would then be maneuvered to an MET facility from which the LH₂ tank had been removed to expose a set of attachment points on the bottom of the METCU. A mating would then be effected by the Orbiter manipulator arms so that the new factory would receive services such as power and communications from the METCU. The new factory could easily be manned by using the habitability module concept and would be serviced as necessary by the Shuttle. Each factory would require a separate MET unit, and perhaps an upgraded power source. This last requirement could be provided at minimum cost by designing the original MET power modules to be stacked on top of each other. The general concept is illustrated in Exhibit 6-14.

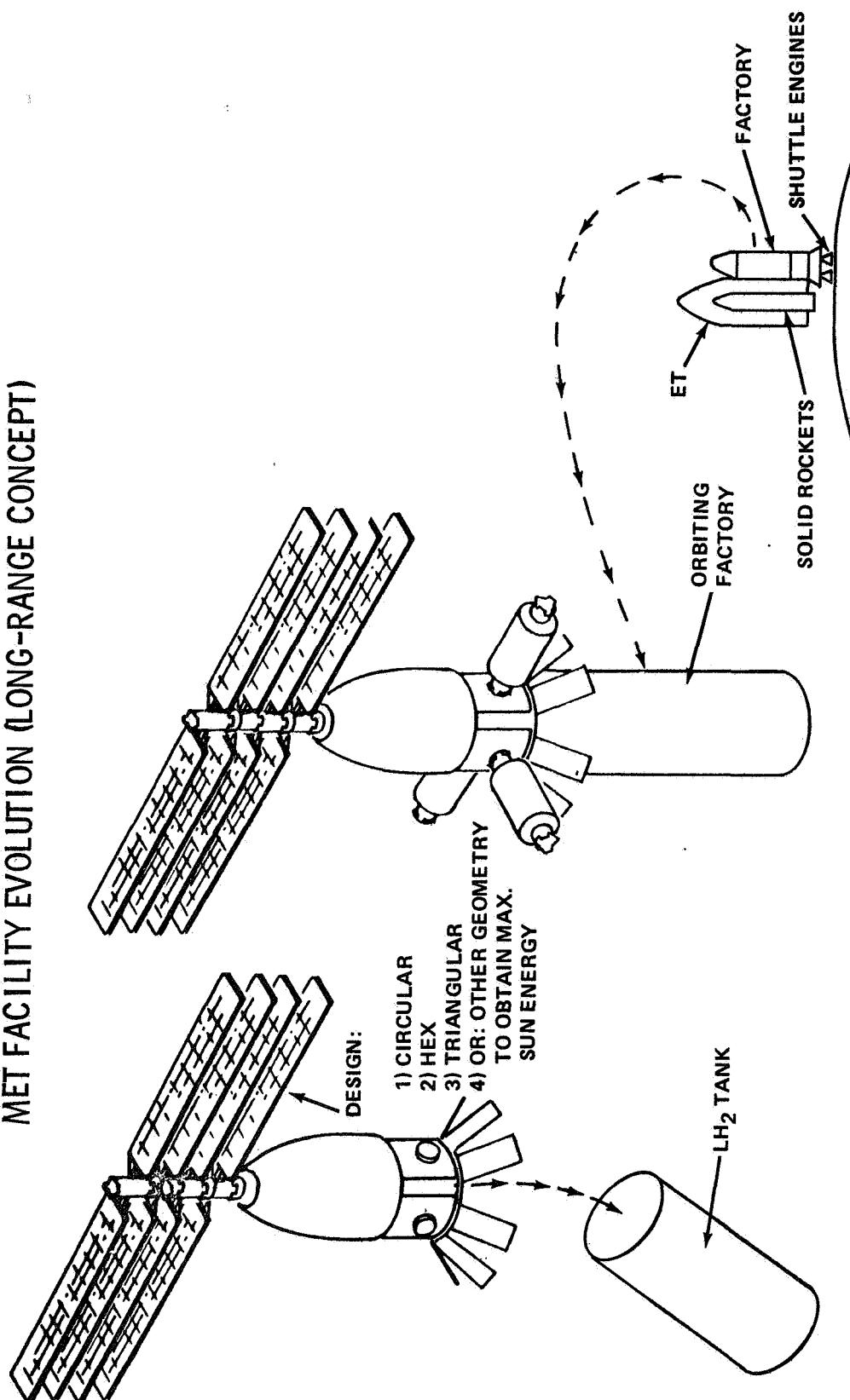
The MET concept just developed, although it contains a few details, is not intended as a blueprint for constructing the facility. Rather, it should serve to illustrate one approach to creating an environment that will motivate the necessary capital investment from private industry to make space manufacturing a self-supporting field of endeavor. The key ideas are low cost, compatibility with industrial processes on Earth, and ease of evolution. Before a process is deployed in space, a great deal of preliminary work must be done on Earth. A further means of motivating space manufacturing might involve the development of research and development facilities on Earth that are oriented strictly toward products with potential for space production. Such facilities are the subject of Chapter 7 and will not be considered here. However, a related topic concerns the provision for secure areas near the STS launch site where the user could assemble and test his module. An obvious solution is for NASA to provide such an area with services, such as power, that duplicate those of the actual MET facility. Checkout could then be done with complete security, if desired, and the sealed module delivered to the Shuttle when ready.

6.5 ADVANCED MANUFACTURING FACILITY

The use of the external tank as a basis for large structures is receiving considerable attention. The need for larger laboratory facilities and longer time in orbit will be necessary, probably near the end of the

Exhibit 6-14

MET FACILITY EVOLUTION (LONG-RANGE CONCEPT)



century. One concept of a larger structure is shown in Exhibit 6-15. The platform is formed by connecting a group of four external tanks from four previous Shuttle flights. The arrangement allows for large amounts of laboratory and processing space in a planar arrangement.

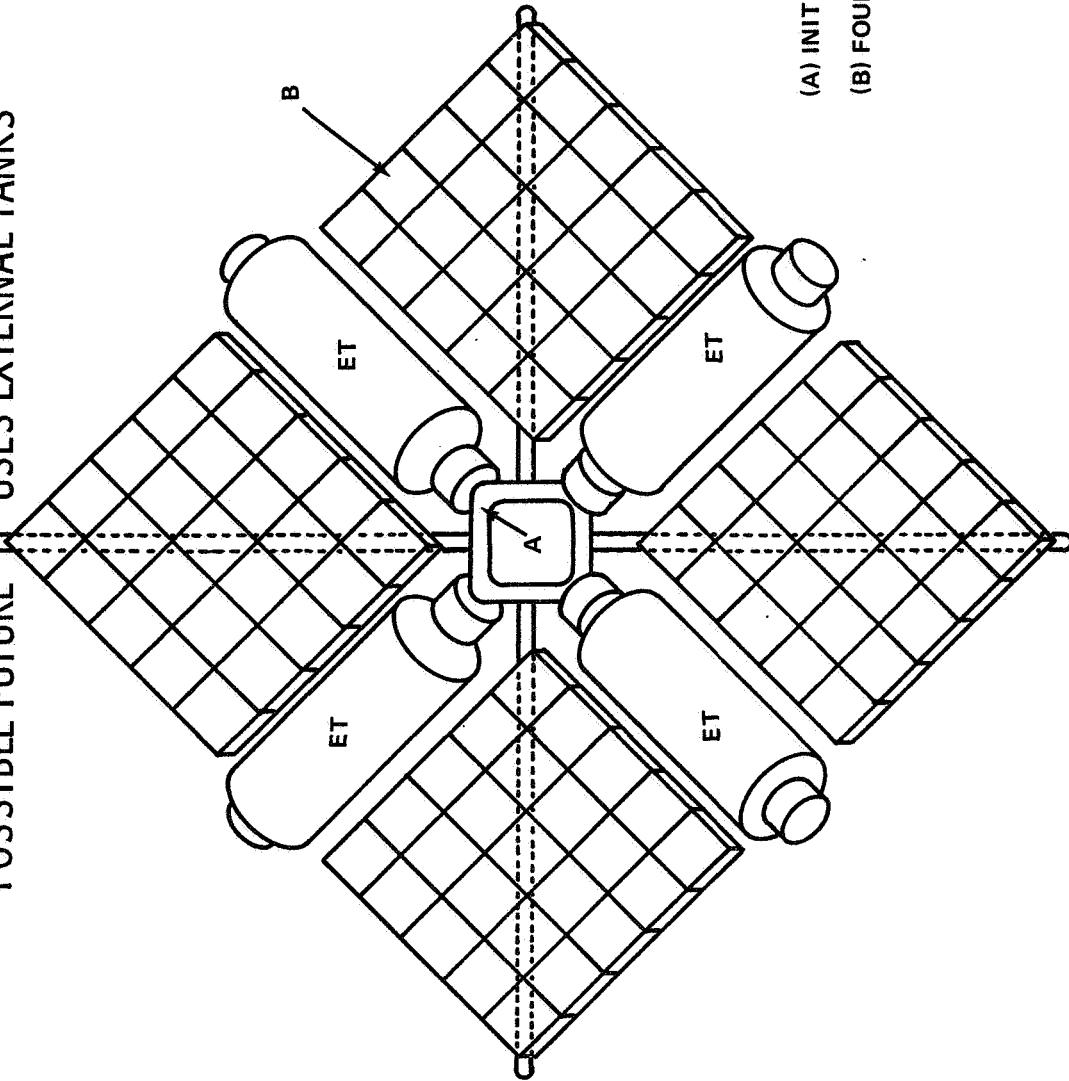
The Shuttle bay contains sufficient volume to store considerable amounts of raw aluminum roll stock and the beam processing machinery to construct large space structures [Nevins - 77]. This service capability and the establishment of a platform will provide the basis for further structure development.

Larger structures will be needed in the future:

- To house power generation facilities,
- To use as permanent space stations,
- To use as a space construction base, and
- To support further space industrialization.

Exhibit 6-15

POSSIBLE FUTURE USES EXTERNAL TANKS



- (A) INITIAL BEAM CONNECTORS FOR ASSY, OF FOUR ET'S
- (B) FOUR ROTABLE SOLAR ARRAYS

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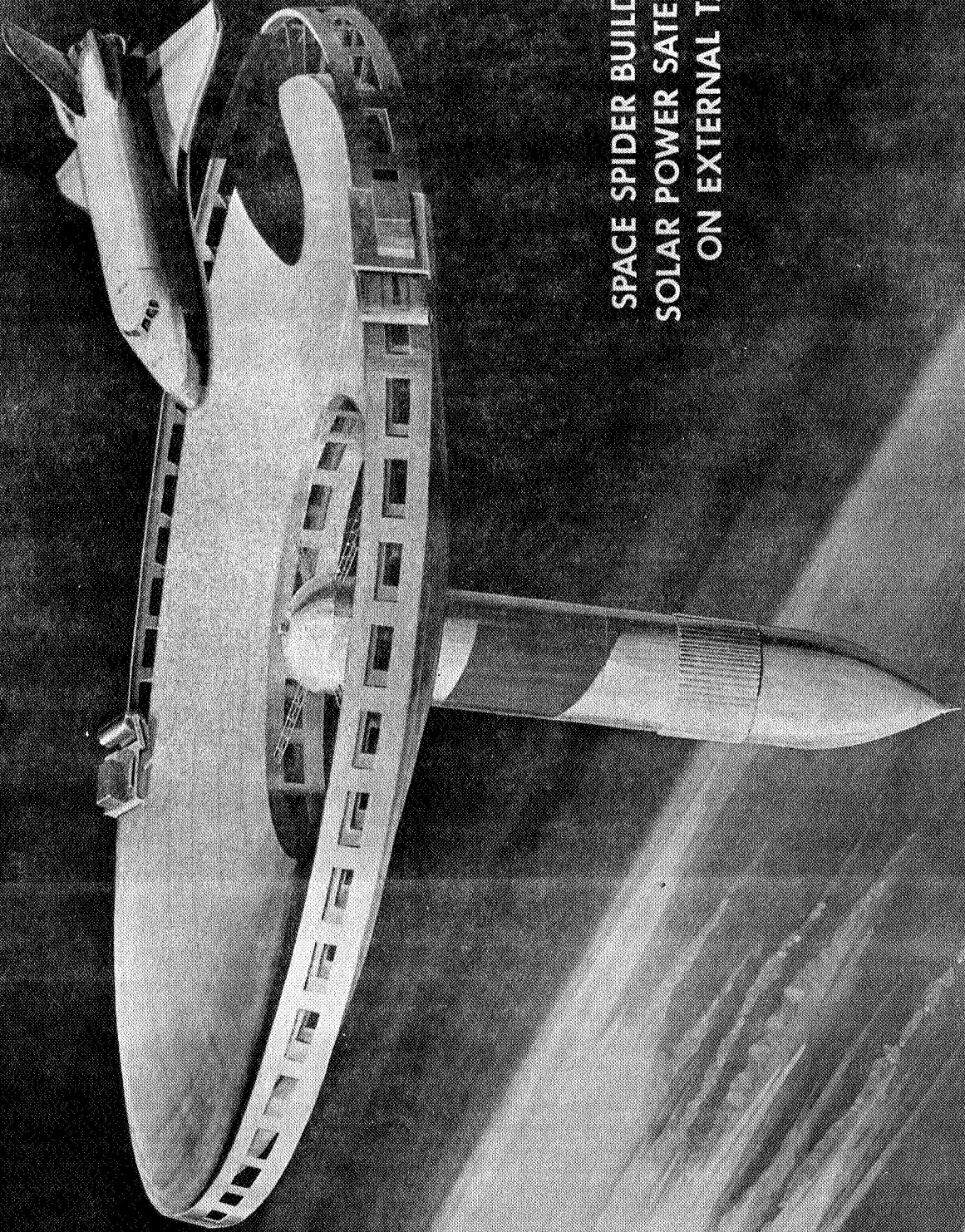
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SPACE SPIDER BUILDING
SOLAR POWER SATELLITE
ON EXTERNAL TANK

MSFC-76-PA 4000-505

CHAPTER 7

GROUND-BASED R&D PLAN FOR MATERIALS PROCESSING IN SPACE

7.1 INTRODUCTION

This chapter outlines the need for ground-based research and development (R&D) related to materials processing in space and develops a plan for its evolution. The major emphasis is given to the life cycle of a product as it grows from an initial idea to commercial production and finally to displacement by a competitive product. This section develops the need for R&D in a technical society and NASA's role in fulfilling that need.

7.1.1 THE ROLE OF R&D TO STIMULATE PRODUCTIVITY AND A BETTER LIFE

Should public money be spent on basic research? The controversy may never end, but R&D must continue if a civilization is to advance its technological frontiers. There will always be disagreement on when to spend money on R&D, who should invest this money and how much should be spent. Many examples can be noted which vividly demonstrate that man is a creative and inventive creature when given the proper environment, inducements and opportunity. While many ideas and creations are simple and immediately useful, many others are dramatic and the impact takes place over long periods of time.

It is generally agreed that civilized nations need to invest a portion of their governments' budget on R&D. On what? When? How much? These become the difficult questions because national priorities are the driving forces which determine the answers. Even though the private consumer ultimately benefits from basic research, it is sometimes difficult for the non-technical person to extrapolate from basic research to increased productivity and a better life. Almost every facet of our lives, from health to education, from the work place to leisure times, from private life to public life, has been touched and enriched by research that was conducted at some prior time.

Econometrics Associates has studied the "spill-over" effects that come from R&D spending. The Chase Econometric Report [Evans - 75] estimated the impact of NASA R&D spending on productivity growth. Productivity growth influences the growth of the economy and real wage rates. The details of the model development are too involved to discuss here, but the conclusions were very significant.

The study showed that a sustained increase in NASA spending of \$1 billion in 1958 dollars for the 1975 - 1984 decade would have these effects:

- "Constant dollar GNP would be \$23 billion higher by 1984 which works out to be a 40 percent return on investment.
- The unemployment rate would be reduced by 0.4 percent in 1984.
- The size of the labor force would be increased through greater job opportunities for a total job increase of 0.8 million.
- The rate of increase in the Consumer Price Index would be reduced to the extent that by 1984 it would be a full 2 percent lower than otherwise indicated."

In summary, the output is higher, the unemployment is lower and inflation is checked [Hearings - 75].

7.1.2 NASA's R&D ROLE

NASA holds a unique role as far as R&D are concerned. Up to the present time, NASA has devoted its primary R&D efforts to transporting men and machines to space without specific regard to the research that could actually be done in space. The extensive effort of the 60's was directed toward putting men on the Moon and returning them safely to Earth. In accomplishing this mission, NASA demonstrated a capability of putting together a diverse team of specialists to perform a designated task. By its very nature all of the direct effort concentrated on a transportation system, but other benefits began to accrue from the increased technical knowledge and experience.

As NASA moves into a new era with the space Shuttle transportation system, it seems inevitable that NASA's R&D position must take on new dimensions -- specifically:

1. A continuation of R&D in all areas pertinent to the Space Transportation System.
2. An active involvement in the ground-based research on space-related problems and potentials both in a sponsorship and coordinating capacity.
3. An active partner in R&D conducted in space.

A practical demonstration of the need for this kind of triad occurred during the Skylab mission when the meteoroid shield and

one large solar array were lost. Many repairs were made during that mission with help from earth-based stations. The MSFC Skylab Mission Report [NASA - 74] describes how an improvised sun shade was devised on the ground and installed by the astronauts to prevent overheating of the workshop.

In the future, ground-based research centers will continue with present research activities, but they will also become involved in support efforts for research to be carried out in space.

Basic research efforts are necessary to keep a viable, healthy culture. The delicate task, of course, is to keep a proper balance between immediate use and reserve know-how. One may recall, for instance, the efforts during the 1890's when scientists were working on the conduction of electricity through gases and found X-rays. At the time the research was probably thought useless, but today it is considered one of the greatest medical discoveries of mankind. Efforts in the space environment will be the same. So many benefits on Earth today are a direct result of space program-related R&D, but we seem to be at a stagnation point and public interest has begun to diminish. This is very unfortunate because we are on the frontier of new discoveries and new knowledge and the effort needs public support. The efforts today on material processing in space will yield vast rewards both in the advancement of knowledge and in the development of products for use on Earth.

7.1.3 MATERIALS PROCESSING IN SPACE R&D

At present NASA is the primary domestic organization for materials processing in space R&D. This work has been in process for a number of years. Experiments have been conducted on Apollo, Apollo-Soyuz, Skylab and SPAR rocket missions. The ground-based support R&D for these experiments was conducted by NASA, aerospace contractors and by government laboratories, such as the National Bureau of Standards (NBS). The current NASA budget for materials processing in space R&D is on the order of \$6 million per year. Dr. Robert J. Naumann heads the Space Processing Division within the MSFC Space Sciences Laboratory.

NASA is currently developing general purpose materials processing equipment and supporting independent researchers in anticipation of the early Spacelab flights. NASA has funded phase A and B studies by GE, McDAC and TRW to design general purpose experimental hardware for use in the Spacelab. A "Request for Proposal" for the development of that equipment is being prepared by NASA. The specific experiments to be conducted on the early Spacelab flights have been selected by NASA from those submitted in responses to a February 8, 1977, Announcement of Opportunity, DA-77-3 (See Appendix G). In general, this experimentation will be conducted by academic researchers with NASA equipment and support. Internationally the

European Space Agency (ESA) is conducting ground-based R&D to support future materials processing in space activities. The Soviets and Japanese are also reportedly working in these areas.

The pertinent question at this point is, "What R&D is required to stimulate commercially viable materials processing in space?" The special space environment properties that seem relevant to materials processing were detailed in Section 6.3.2. Section 6.4.4 developed the potential applications of these space environment properties to materials processing. The key phrase of the previous sentence is "potential applications." Currently, no commercially profitable application of materials processing in space has been demonstrated. Thus, it is readily apparent that further R&D is needed for materials processing in space to become commercially viable. This chapter will develop a general plan for such R&D without discussing the specific details of the processes or products involved.

Before proceeding with the development of an R&D plan, it is important to define its field of interest. While the topic of this report is materials processing in space, such a research direction may be unnecessarily restrictive. Here, the broader view is taken; i.e., research directed toward the utilization of the special space properties for materials processing. This would permit the R&D to focus on the advantages of space, rather than materials processing per se. This may lead to fundamental discoveries in space which significantly improve ground-based materials processing. Specifically, research involving micro-g solidification might lead to a fundamental discovery which dramatically changes the ground-based foundry industry.

7.1.4 SUBSYSTEM DIAGRAM

Exhibit 7-1 is the subsystem diagram for this chapter. The diagram forms the framework for the ideas which will be developed and analyzed.

7.1.4.1 OBJECTIVE AND GOAL

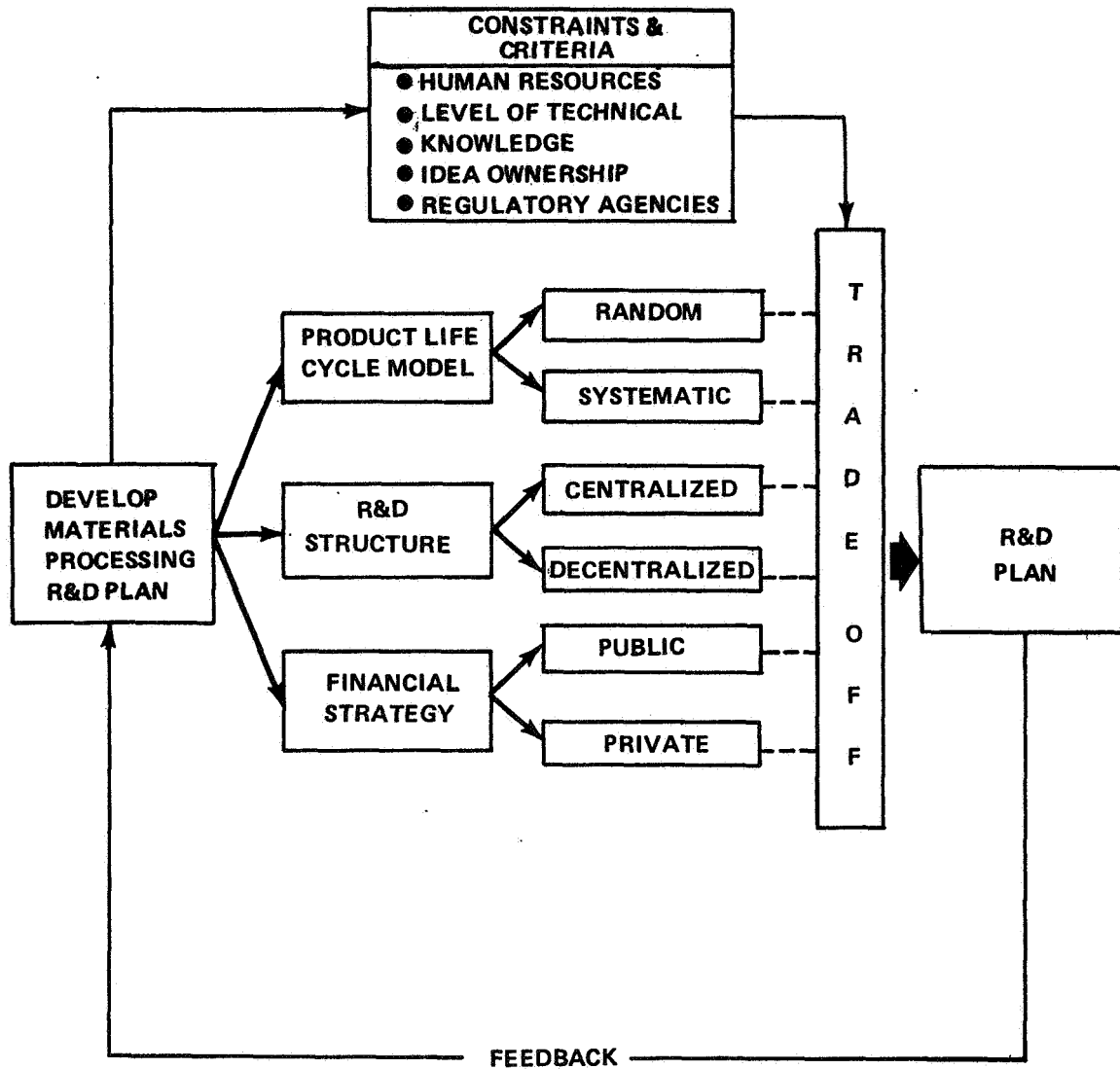
The objective of this chapter is to develop an R&D plan which will lead to commercially viable materials processing in space. The plan will also include the utilization of space as a learning environment for ground-based materials processing.

7.1.4.2 CONTROLS

A set of controls have been defined for this plan. In addition, the controls for the overall system influence the development of this subsystem. The controls are as follows:

Exhibit 7-1

SUBSYSTEM DIAGRAM FOR R&D PLAN



- ° The R&D plan must strive to make maximum effective utilization of the human resources and technical knowledge available to carry out the plan.
- ° The R&D plan must deal with the problem of idea ownership or rewarding the innovator.
- ° The R&D plan must consider the legitimate role of government, particularly in the regulatory sense. Further, it is well to consider what is not being said by the subsystem's controls.
- ° No geographical or political limits have been placed on the R&D plan.
- ° The R&D may be conducted both on the ground or in space as appropriate and the end result or technology may be used in either environment.

The controls on the system which apply directly to the R&D plan are as follows:

- ° The 1985 to 2000 time frame must be viewed as the results period for the R&D effort. The actual R&D activities must be initiated prior to 1985 and, in fact, are currently underway.
- ° The NASA budget is assumed to have a ceiling of 1 percent of the Federal budget. This constraint is not overly active in the R&D plan because the plan funding would be substantially below that level. In addition, materials processing in space R&D may involve non-NASA funding sources, such as, NSF, DoD, ERDA and private industry.

7.1.4.3 REQUIREMENTS/ALTERNATIVES

Three requirements or necessary components appear essential to the development of ground-based R&D plan for materials processing in space:

- ° Product Life-Cycle Model
- ° R&D Structure
- ° Financial Strategy

Within each of these requirements a continuum of alternatives exists. These requirements and their alternatives are now briefly introduced. Later sections will develop each in detail and a tentative recommendation will be made.

The section discussing the Product Life-Cycle Model illustrates the means by which an idea or innovation is converted into a commercially profitable product. Model alternatives range from a random process to a planned systematic approach. An understanding of the steps involved is necessary to develop the structure and financing of the R&D plan.

The section discussing the R&D structure sketches the organizational form used to direct the desired activities. Structure alternatives range from a single ground-based laboratory to the decentralized, non-structured approach. Because of the number of potential R&D activities and areas, a variety of the structures may be desirable.

The section discussing financial strategy explores the problem of funding R&D and the mechanism to justify such investments. Financing alternatives range from totally public to totally private funding. Due to the number of R&D activities, it is likely that a combination of financial strategies may be required to develop commercially viable materials processing in space.

7.1.5 R&D PLAN REVIEW

The final section of this chapter completes a tradeoff analysis of the three requirements and their respective alternatives. Several R&D plan recommendations are presented with an emphasis on the immediate steps to be taken to encourage the commercialization of materials processing in space.

7.2 PRODUCT LIFE-CYCLE MODELS

This section addresses the question of how a new idea becomes a commercially viable product. More specifically related to the materials processing in space problem, how can the space environment be profitably used in processing materials useful to mankind? Some traditional means of innovation are first discussed, then two distinct alternative models from the continuum of possibilities, and, finally, the tradeoff analysis and recommendations.

7.2.1 MEANS OF INNOVATION

Two classic stereotypes exist for innovators; the laboratory scientist and the basement inventor. Certainly, both these types of individuals have had a part in our technological society, but perhaps that role, while important, has been overstated. No doubt a new idea or fundamental scientific discovery is necessary for new product development, but it is far from sufficient. Numerous steps must follow the initial innovation to bring that idea to the commercial market in a successful manner.

7.2.2 ALTERNATIVES

A continuous set of product life-cycle model combinations could be addressed. In the interest of brevity, only the two extremes are presented. First, the random procedure which might be followed by an individual inventor and then a systematic approach which represents an ideal for corporate or governmental activities.

7.2.2.1 RANDOM MODEL

Nearly everyone has some hope to invent a product, manufacture it, and become rich. Men like Edison, Bell and Henry Ford fit that inventor/entrepreneur image. Those men made their fortunes by successfully converting ideas into commercial ventures. How can today's inventor make that transition? Apparently, the path is still open, at least in limited areas such as computer peripheral hardware and biomedical equipment. However, the government and general social concerns have made the path difficult to follow. Regulatory agencies like OSHA, ICC and FDA and concerns such as product liability and consumer protection make new venture entry extremely difficult. Thus, the private inventor/entrepreneur faces a difficult task. In addition, even if the initial product is successful, the development of a second product may be difficult. Zarecor highlighted a problem faced by high-technology business. Many firms started and made successful by an inspired hunch (innovation) rapidly die for lack of a second product. He outlines a procedure for increasing the probability of survival of high-technology business [Zarecor - 75].

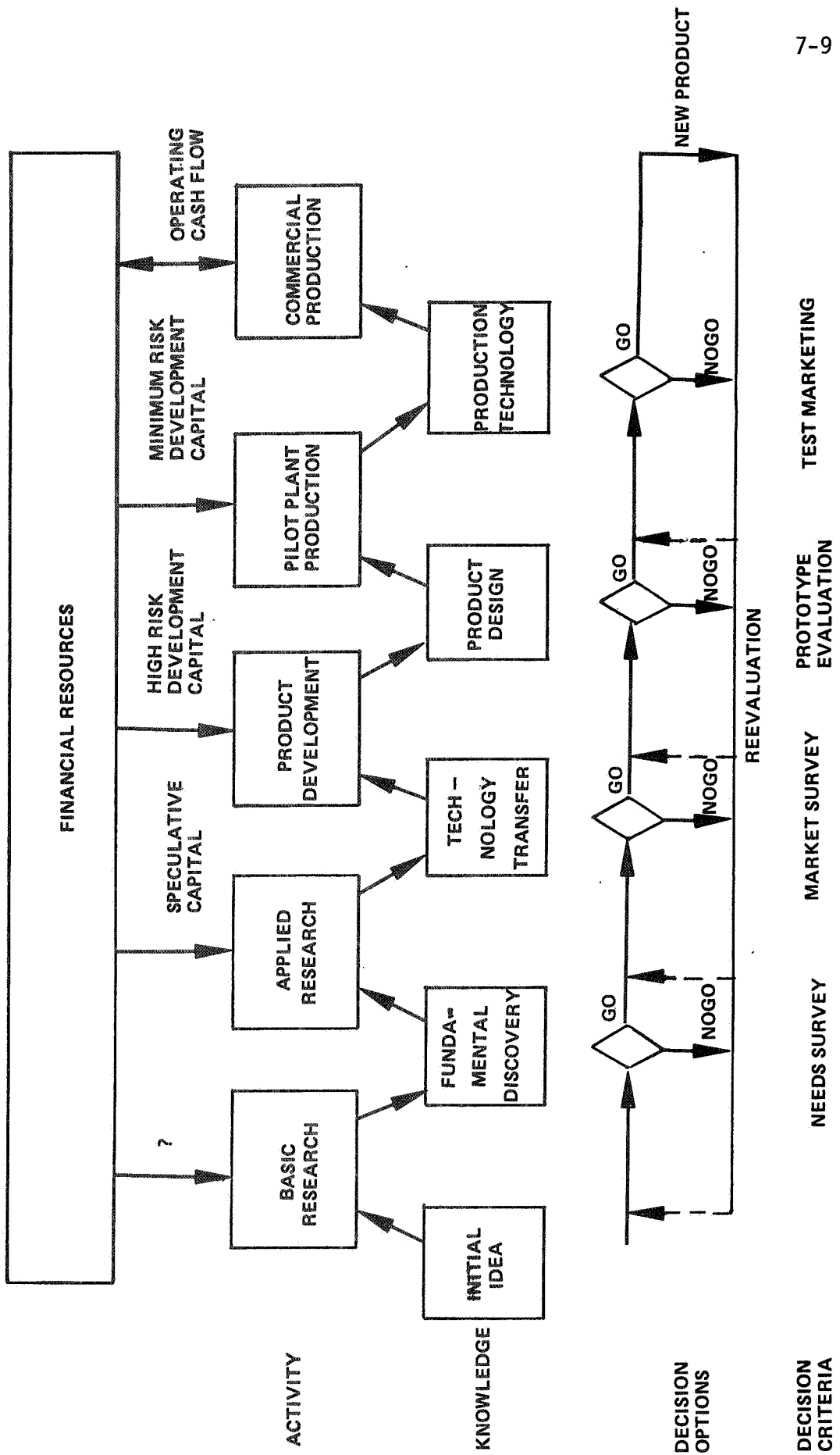
The private innovator who does not want to enter the business world can, after sufficient development effort, attempt to patent and then market his idea. The economics of such a plan seem doubtful when one considers the time and money required to first obtain a patent and then to market the idea. In short, the private inventor has a difficult task in today's market place. The problem appears even more difficult in high-technology areas such as materials processing in space. A scheme for aiding the private innovator is presented in Section 7.3.5.

7.2.2.2 SYSTEMATIC MODEL

Exhibit 7-2 is a product life-cycle flow model. It indicates the financial resources used, the activities performed, the knowledge generated, the decision options and the decision criteria used to transform an idea into a product. The product life-cycle activities are: Basic research, applied research, product development, pilot plant production and commercial production. Basic research begins with an initial idea, a nagging question or lack of knowledge and attempts to find the missing link or fundamental discovery. If an apparent need exists, applied research refines the fundamental discovery into a technology which can be transferred to the product

Exhibit 7-2

PRODUCT LIFE CYCLE FLOW MODEL



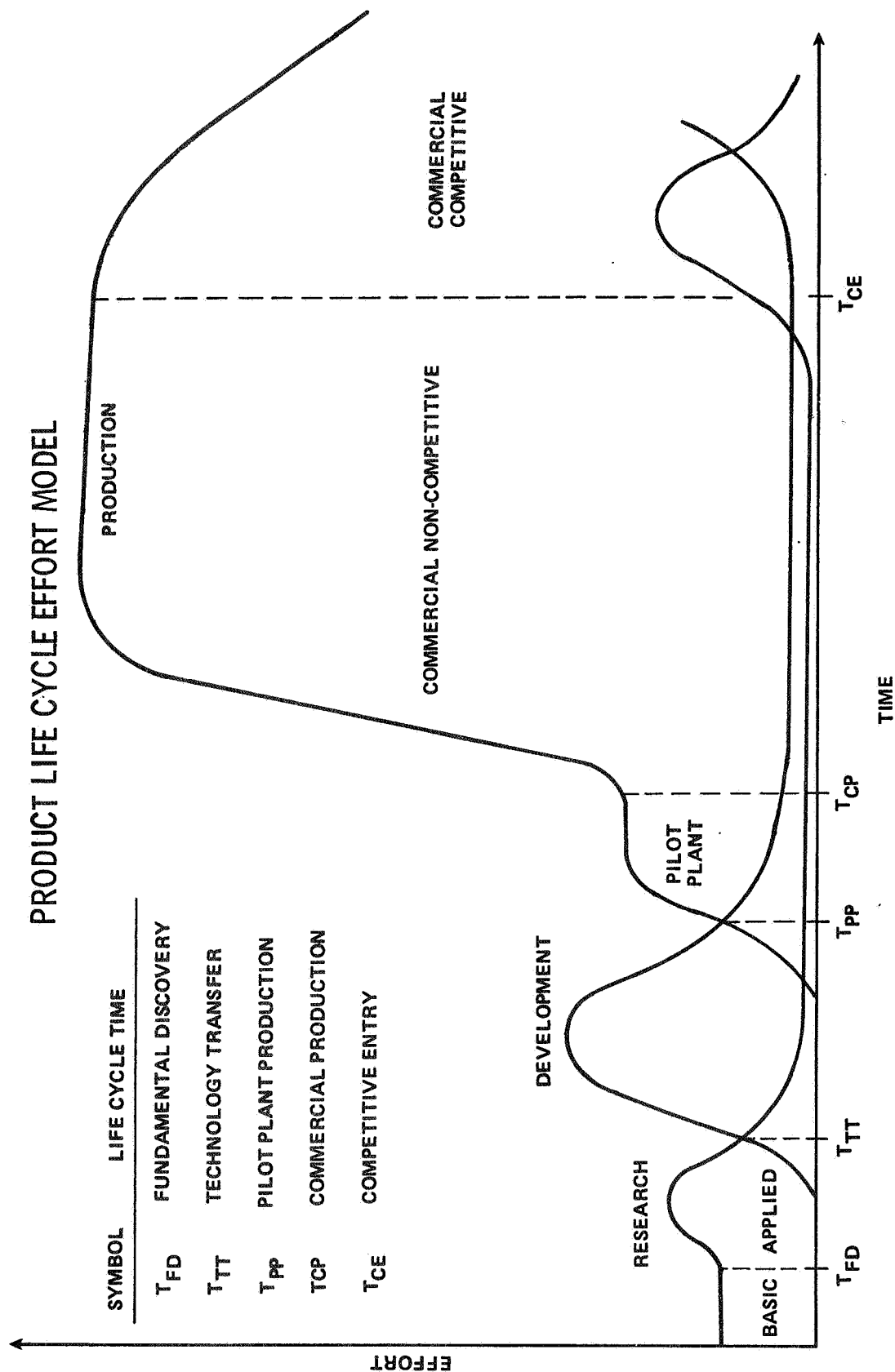
development engineer. If a potentially profitable market can be identified, the product development engineer designs the product. If the product prototype meets the design criteria, pilot plant production is begun to test the production technology and to provide product samples for test marketing. If the pilot plant production technology and the test marketing is successful, commercial production is begun.

Each product life-cycle activity requires the commitment of financial resources. The source and form of funding is dependent upon the relative risk associated with the potential product at any particular point in its life cycle. Funding for commercial production is relatively straight forward and should rapidly become self-supporting as a positive cash flow is generated by product sales. On the other hand, funding basic research is extremely difficult in all but large, high-technology corporations with a proven success record or a strong desire to maintain a technologically competitive advantage. R&D financial strategies are further discussed in Section 7.4.

The product life-cycle activities are linked together by a flow of knowledge and a decision option. The knowledge gained in the previous activity, a subjective evaluation of the product's market potential and the availability of resources (manpower, financing and facilities) all must be considered in order to determine the direction of the product's next step. A positive decision (go) initiates the next activity. A negative decision (no go) results in a re-evaluation of the product and a new start at some prior activity (Exhibit 7-2). Few initial ideas survive to become commercially viable products because of the number of decision points involved and the rigid screening process at each decision point. Grumman's Space Manufacturing Concepts Study [Grumman - 77] indicates that 60 to 100 initial ideas are required to produce one new food product; 2000 to 5000 ideas for a new ethical drug and about 10,000 for a pesticide. Thus, the fall-out rate is very high and conversely, the expected payback from basic research is very low unless numerous product ideas can be generated from a single fundamental discovery. Most commercial organizations have scores of product ideas simultaneously at various life-cycle points.

The time required for each product life-cycle activity is highly variable. For example, the fundamental discovery from basic research may occur in a few days or could require years, even a lifetime. The relative effort level and timing for each product life-cycle activity is illustrated in Exhibit 7-3. This effort model illustrates an overlapping of product life-cycle activities. Basic research continues at a constant effort level until time T_{FD} , fundamental discovery. The effort level then grows as the applied research is conducted. This effort peaks and then declines as the knowledge gained is gathered for technology transfer at time T_{TT} . From time T_{TT} the research activity

Exhibit 7-3



further declines to a relatively low sustaining effort. The product development activity starts just after the peak of the research activity. Up until time T_{TT} the development effort is of a feasibility study nature. After time T_{TT} the development effort grows while alternative designs are being considered, peaks at the time a final design is chosen and declines as the design details are determined and the prototype is built. Time T_{pp} represents the start of the pilot plant production activity. As with the interface between research and development, an overlap of effort occurs between development and production. Unlike the research and development effort curves, the production effort curve reaches two stable levels: the first during pilot plant production and the second during commercial production. Time T_{cp} marks the start of the commercial production activity. The initial portion of the commercial production era is assumed to be non-competitive where the product's demand grows to its natural level of stability. At time T_{ce} a competitive product is assumed to enter the market and begins to displace the demand for the original product. Notice that at about time T_{ce} both the research and development efforts must be reinitiated to begin a new product life cycle. The successful high-technology firm will foresee the competitive entry point, initiate the R&D early enough to maintain its market positions. In fact, a multi-product firm may actually be creating its own competitive new products to keep its product line fresh in the eyes of the consumer.

The Charpie Report, published in 1967, estimated that a "typical distribution of costs in successful product innovation" would be:

Research/advanced development/basic invention (Basic and Applied Research)	5 - 10%
Engineering and designing the product (Product Development)	10 - 20%
Tooling/manufacturing engineering (Pilot Plant Production)	40 - 60%
Manufacturing start-up (Commercial Production)	5 - 15%
Marketing start-up (Not Modelled)	10 - 25%

These estimates are of great significance because of the place of R&D in the cost distribution -- it is the least costly of all the activities. Even when a government financially supports a R&D effort, the remaining costs of the product life cycle borne by the company are normally greater than the government assistance [Stead - 76].

7.2.3 TRADEOFF ANALYSIS

Of the two alternatives just presented for product life-cycle models from the continuum of those possibilities only the systematic option is tractable to analysis.

7.2.4 LIFE-CYCLE MODEL RECOMMENDATIONS

It is recommended that the systematic product life-cycle model be used to guide the development of the R&D plan for materials processing in space. Planning must initially focus on basic research since there have been few fundamental discoveries in the field of materials processing in space.

7.2.5 RECOMMENDATIONS FOR IMPROVING TECHNOLOGY TRANSFER

The transfer of knowledge from one product life-cycle activity to the next functions relatively efficiently within a single high-technology firm. Steele [Steele - 75] has several suggestions for improving this flow within an organization. The problem of knowledge transfer becomes more difficult when different organizations conduct the various product life-cycle activities. Take the typical case of government-supported basic and applied research with private product development and production. Technology transfer from government laboratory to private industry can be a barrier to the timely introduction of a new technology. Since the Federal Government is a major supporter of research, many agencies are extremely aware of this problem. Wishing to show a payback from their research expenditures within a relatively short time and to encourage the adoption of new technologies, the government has chosen to expand its product life-cycle activities. Not only has the government taken on the product development activity, but also the pilot plant production activity in the form of project demonstrations. A Rand Corporation study [Baer - 77] has examined the effectiveness of a number of such research, development and demonstration (RD&D) efforts. Exhibit 7-4 presents an information flow model for demonstration projects. The Rand study concluded that government-funded demonstration projects are most appropriate and effective for projects in the middle range of uncertainty. Demonstrations are not cost-effective substitutes for laboratory experiments, field tests, or pilot projects when the technological uncertainty is high. Materials processing in space fits the latter category.

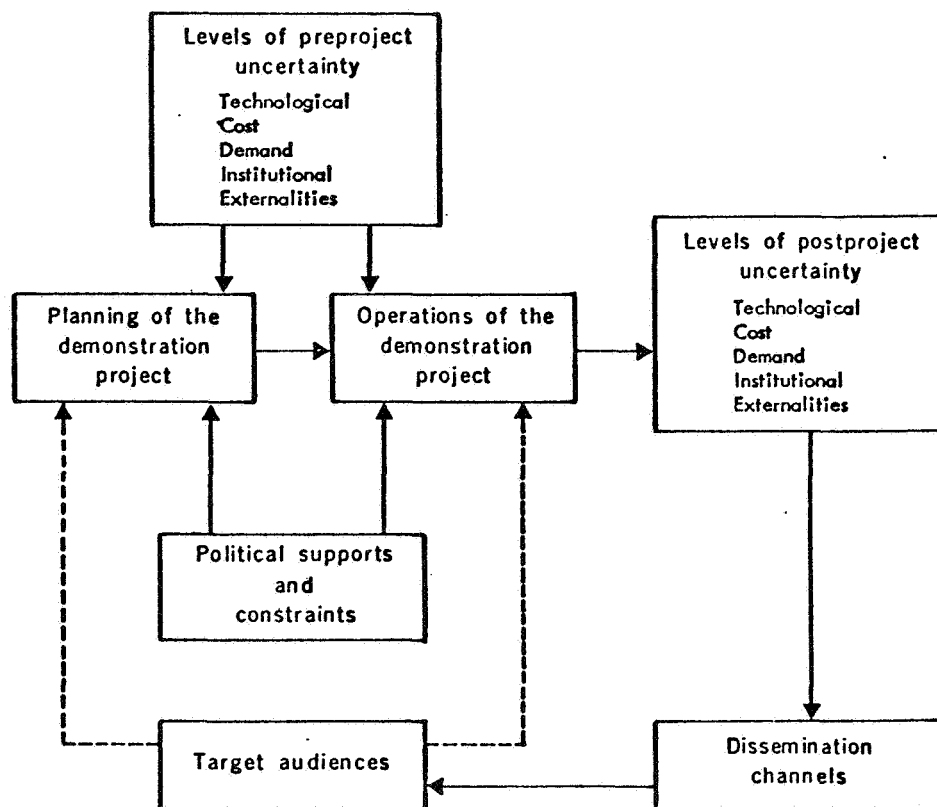
7.3 R&D STRUCTURES

The previous section developed a conceptual model of the product life cycle from basic research through commercial production. A systematic model of this evolution is required if one is to study the means of stimulating or planning the R&D activity. With that model in mind, this section surveys some potential R&D structures (reflecting current practice and trends), presents a continuum of alternative R&D structures and analyzes them using the systems approach.

7.3.1 SURVEY OF R&D STRUCTURES

In days past, innovators like Franklin, Jefferson and Whitney

Exhibit 7-4

DEMONSTRATION PROJECTS
INFORMATION FLOW MODEL

[Baer - 77]

worked individually to transform their ideas into commercial products. As the industrial revolution progressed, the product life cycle became more complex and teams of scientists, engineers and technicians, using sophisticated laboratory equipment, were required to develop new products. The government uses a variety of R&D structures. The Fermi National Accelerator Laboratory at Batavia, Illinois, built in 1972 at a cost of \$243 million [Bylinsky - 77], illustrates large-scale R&D. Other R&D projects related to the breeder reactor and coal gasification approach that scale. On the other hand, grants from the National Science Foundation (NSF) to individual college professors represent the opposite extreme.

Several trends have been noted in the R&D spending of the government. After a rather stable spending level during the early 1970's, total real dollar spending has recently begun to increase slightly. An increasing share of the governmental R&D dollar is going to contractors as opposed to governmental laboratories. An increasing share of the governmental R&D dollars is going to civilian technologies (energy, transportation, etc.) rather than governmental technologies (military, space, etc.).

The degree of scientific concentration has been studied in various countries of the world [Inhaber - 77]. The scientists of the United States and the Federal Republic of Germany were found to have the greatest degree of physical dispersion. Almost all countries had a greater degree of dispersion in 1972 as compared to 1967.

7.3.2 ALTERNATIVES

When seeking an organizational structure for conducting the ground-based R&D necessary to promote materials processing in space the possible alternatives range from a single national or global laboratory to allowing the individual innovator to work independently without any formal support. As in the case of the product life-cycle model, a continuum of intermediate alternatives exists. Exhibit 7-5 outlines five specific alternatives from that continuum. These alternatives may also be developed on a continuous scale from centralization to decentralization.

The single laboratory model would be patterned after the Fermi National Accelerator Laboratory. This lab would concentrate all preparation R&D for materials processing in space activities in a single facility. The majority of the work would be done by in-house scientists, engineers and technicians. Members of the academic community would be encouraged to join the staff through sabbatical and summer fellowship programs. Members of the industrial R&D community would be encouraged to join the staff on a temporary basis through exchange and cost-sharing programs. Some of the laboratory's facilities may be made available to outside researchers on an exclusive

Exhibit 7-5

GROUND-BASED R & D STRUCTURE MODELS FOR MATERIALS PROCESSING IN SPACE

ALTERNATIVES MODELS		NON-FINANCIAL TRADE OFFS		
FIVE REPRESENTATIVE POINTS ON THE CONTINUUM OF ALTERNATIVES	DEGREE OF CONTROL	POTENTIAL FOR KNOWLEDGE EXCHANGE	POTENTIAL FOR INNOVATION	LEVEL OF EFFORT FLEXIBILITY
SINGLE LABORATORY (FEMILAB MODEL)	HIGH	EXCELLENT SEMINARS INFORMAL EXCHANGE	LIMITED BY BUREAUCRACY FORMAL PROCEDURES MAY RESTRICT INNOVATION	STAFF REDUCTIONS WOULD BE PAINFUL MISSION SHIFTS WOULD BE LESS PAINFUL
REGIONAL LABORATORIES (AGRICULTURAL RESEARCH MODEL)	HIGH	EXCELLENT WITHIN A LIMITED EXCHANGE BETWEEN LABS	SAME AS ABOVE COMPETITION BETWEEN LABORATORIES MAY HAVE AN EFFECT	STAFF REDUCTIONS AND MISSION SHIFTS BETWEEN LABS WOULD BE PAINFUL
AGENCY/CONTRACTOR (NASA MODEL)	MEDIUM	LIMITED BY COMPETITION AND CONTRACT-REGULATIONS REPORT MIGHT BECOME PUBLIC PROPERTY	TWO DIFFERENT SOURCES OF INNOVATION COMPETITIVE REVELRY MAY HAVE AN EFFECT	CONTRACTOR WOULD BEAR THE BURDEN OF CHANGING STAFF LEVELS CONTRACTING TEND TO HAVE THE FEAST/FAMINE SYNDROME
GRANTS/TAX CREDITS (NSF/IRS MODEL)	LIMITED	RESTRICTED BY COMPETITION COULD BE OPENED BY DISCLOSURE REGULATIONS	MANY SOURCES AT INNOVATION RESTRICTED BY CONTRACT GUIDELINES AND REGULATIONS	GENERALLY QUITE FLEXIBLE PRESENTS A SOFT-MONEY PROBLEM TO THE ACADEMIC COMMUNITY
NON-STRUCTURED (FREE WILL MODEL)	NONE	VERY RESTRICTED BY COMPETITION LIMITED TO TECHNICAL PAPERS AND PATENT DISCLOSURES	VERY OPEN TO INNOVATION BUT THE INDIVIDUAL RESEARCHER MUST SEEK FUNDING TO DEVELOP IDEAS	VERY FLEXIBLE

DE-CENTRALIZED ← CENTRALIZED

leasing arrangement. The laboratory's work might span the range of product life-cycle activities from basic research to pilot plant production. It could also include the commercial production of specialized products, such as military hardware components. The laboratory would rely heavily on government funding. Its funding base could be either national or international in scope.

The regional laboratories would be essentially the same as the above alternative, but would be divided into several distinct laboratories, each with a specific mission. The regional laboratories might be patterned after the agricultural research program at the land grant universities. The mission may be along the lines of space properties; e.g., micro-g, high vacuum, low vibration, or by areas of application; e.g., bio-medical products, metals, glasses, etc. Only limited interaction between the laboratories would be expected due to their mission differences.

The Agency/Contractor model is essentially NASA's current operational plan. This follows a general trend in Federal Government R&D to a relatively small central staff with the majority of work being done by contractors.

The Grant/Tax Credit model corresponds to the structure of the National Science Foundation. This model is characterized by a limited central organization with peer review of proposals from academic researchers. General tax credits or incentives would be used to promote corporate R&D. For example, space equipment might be expensed rather than capitalized; thus, having a cash flow advantage over ground-based investment.

The Non-Structured model would simply expect industry and private innovators to enter the materials processing in space R&D game with their own funding or by obtaining funds from other agencies such as NSF.

7.3.3 TRADEOFF ANALYSIS

Exhibit 7-5 summarizes some of the major non-financial tradeoffs associated with the ground-based materials processing R&D structure models.

The degree of control or the ability to plan the R&D activities is proportional to the degree of centralization. The single laboratory could very closely plan each experiment; thus, eliminating any duplication of effort. The non-structured model would lack any type of control and might find the same experiment being duplicated by many researchers. The other alternatives have intermediate degrees of control.

The potential for knowledge interchange also is proportional to

the degree of centralization. Seminars at the single laboratory could be used to inform other researchers with a minimum of expense. Informal exchange of knowledge would also occur readily. The non-structured model would provide for knowledge exchange only through technical papers and patent disclosures. A considerable amount of proprietary information would never be exchanged.

The potential for innovation is inversely proportional to the degree of centralization. The bureaucracy associated with the single laboratory might limit innovation through formal operating procedures. The non-structured model would be very open to innovation. However, the innovator might find it difficult to gain support to continue an R&D effort.

The level of effort flexibility or the ability to change the direction, scope and size of the effort is inversely proportional to the degree of centralization. Changes, other than minor mission shifts, would be painful to the single laboratory. The non-structured model could adapt readily to changes in the level of effort.

7.3.4 R&D STRUCTURES RECOMMENDATIONS

It is not possible to recommend one R&D structure model to fit all of the activities associated with a product life cycle. Rather, some hybrid combination of models seems to be called for. Section 7.5 addresses this recommendation in further detail.

7.3.5 RECOMMENDATIONS FOR GROUND-SPACE INTERFACES

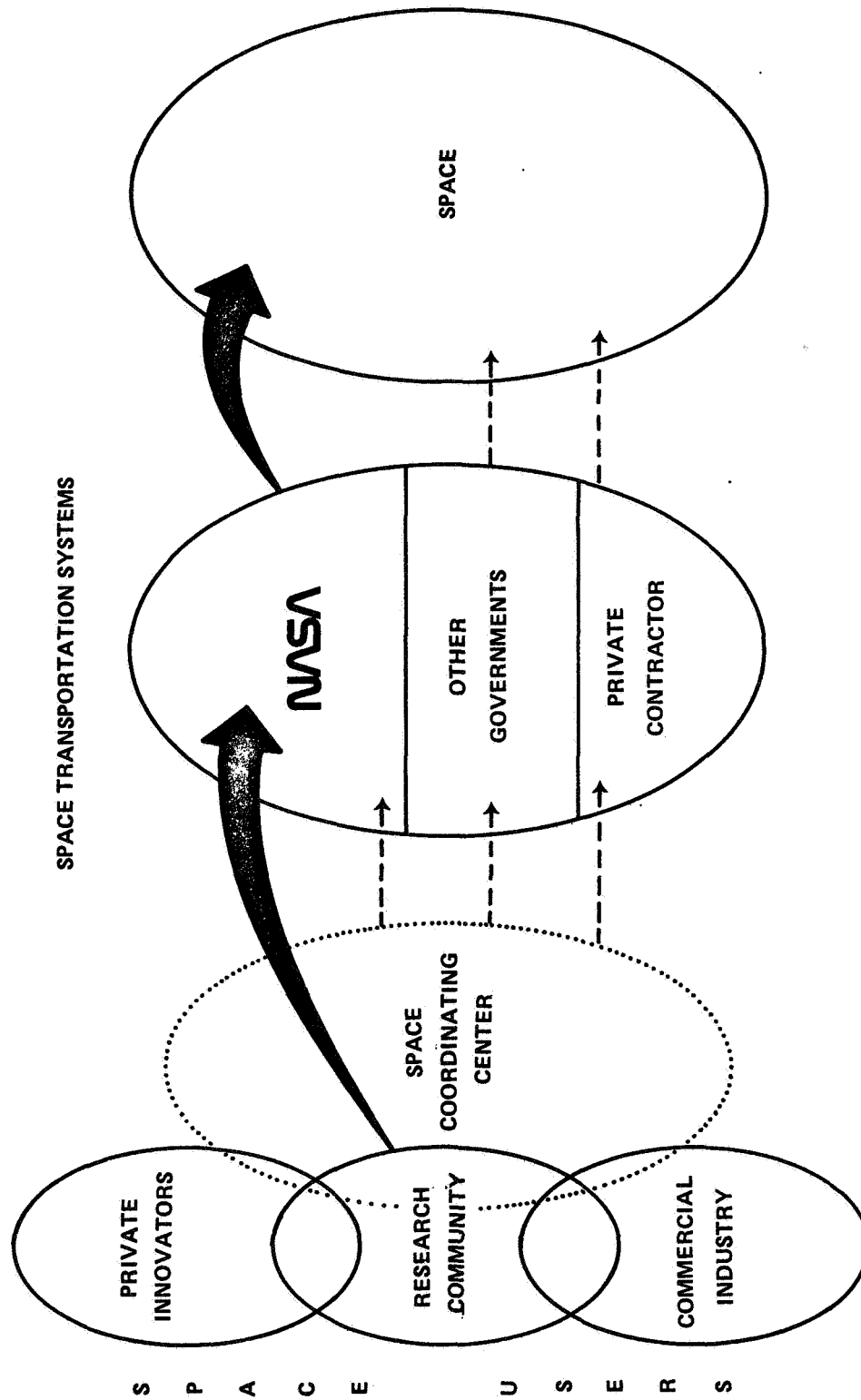
Thus far, only the ground-based R&D portion of the materials processing in space problem has been addressed. This ground-based effort will no doubt represent the major portion of the R&D activities performed in the field of materials processing in space over the next decade. Preliminary experiments, space laboratory equipment and data analysis will all be done on the ground. Actual orbital experimentation will likely consume no more than a small fraction of the total effort. That fraction will grow only after materials processing in space has moved out of the R&D phase into pilot plant and commercial production. Even during commercial production, only 5 - 10 percent of the manufacturing processes are likely to be conducted in space.

Exhibit 7-6 illustrates the user and space interfacing model. First, consider only the solid line portion of the exhibit. On the left are the potential space users: The research community, private innovators and commercial industry. In the center is the link to space or the Space Transportation System. Today, NASA has the only such system in the free world. In the future, other government or private contractors could provide such services. On the right is the goal or space.

Currently, it seems that only the research community, and a

Exhibit 7-6

AN INTERFACING MODEL FOR USERS AND SPACE



limited segment of that, has the know-how to contract with NASA for space transportation services. COMSAT would represent the one exception to the general rule. It seems appropriate to establish a Space Coordinating Center to serve as a facilitator between the space user and the space transportation system. It would add a significant degree of flexibility and strengthen NASA's public image if the Space Coordination Center could be established as a separate office within its existing structure.

The Space Coordination Center would be ground based and have as its primary function the interfacing of private, industrial and governmental agencies to the space program. It would contain certain functions in the developmental area now being managed by NASA and would bring to one center the technical and managerial capability to assist a wide cross-section of users.

A major function of the Space Coordination Center would be to advise potential users of the possibilities and the known limitations of the space environment. The Center would coordinate all private use of the Space Transportation System. It would assign priorities and payload positions in the interest of all space users.

Another function of the Space Coordination Center would be to administer the "New-User Special" Space Shuttle flight discount program. Exhibit 7-7 illustrates the "New-User Special" flight discount program used to encourage new space users. The basic idea is to offer the new space user a discount from the actual space flight cost of C_A . The discount on the first flight might be as much as 95 percent or cost C_1 . On the second flight, an 80 percent discount or cost C_2 would be charged. The third flight would have a 50 percent discount or cost C_3 . All subsequent flights would be paid for at the full cost, C_A . Each user organization would be permitted one set of three discount flights.

7.4 FINANCIAL STRATEGIES

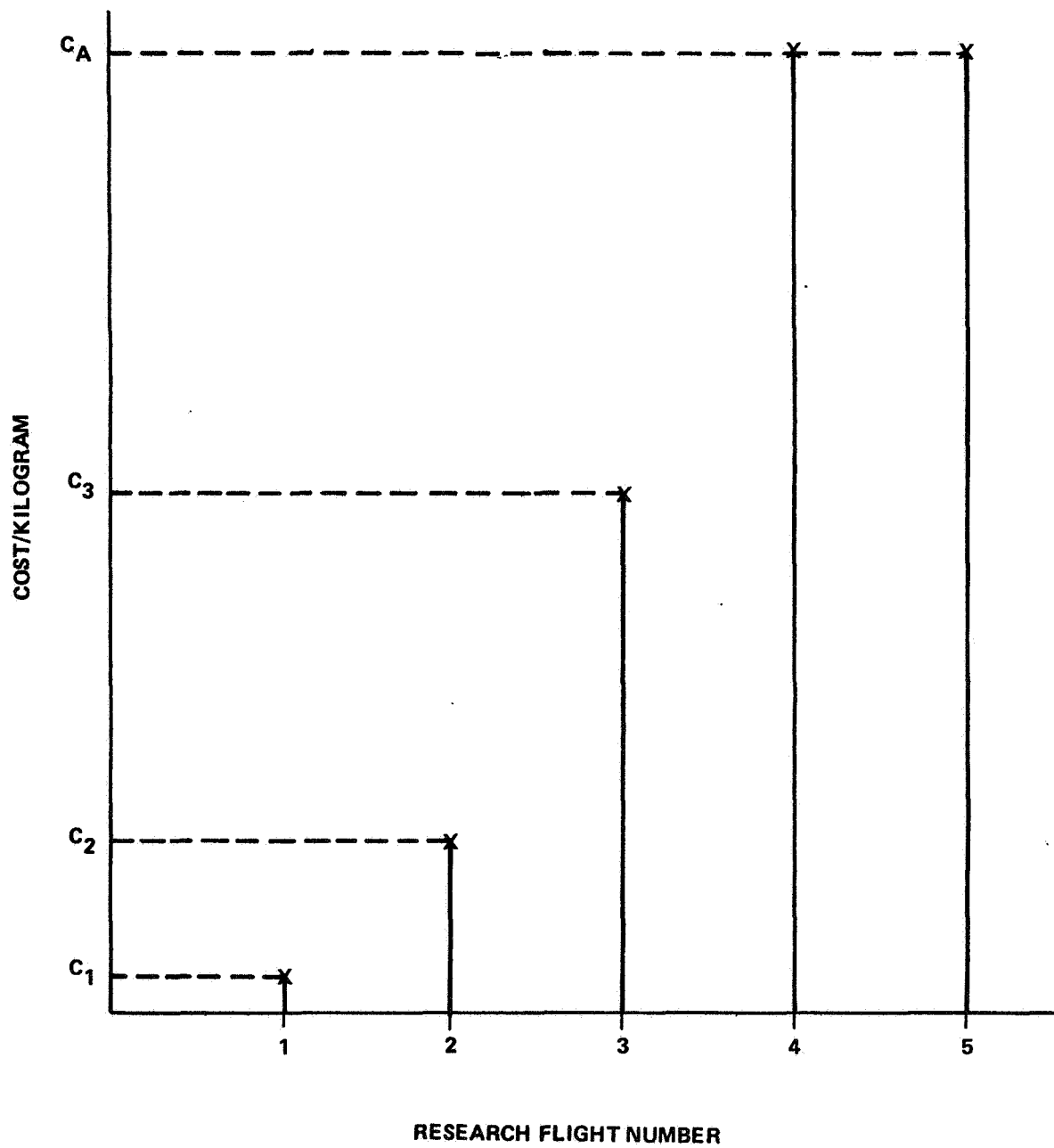
Financial strategies become very complicated when trying to incorporate government involvement into the normal financial structure of private industry. As long as funding policies remain entirely public, the lines of responsibility and corresponding rewards are fairly well defined. Likewise, when private individuals or private industries invest funds, the ideas or patents which evolve and any profits which may accrue belong to the investors. Likewise, the investors must bear any losses if the venture is unsuccessful. The difficulties develop when public money is used to support private projects and the patent ownership becomes uncertain.

7.4.1 FINANCIAL EVALUATION MODELS

Before discussing the alternative methods of funding ground-

Exhibit 7-7

"NEW-USER SPECIAL" SPACE
TRANSPORTATION COST MODEL



based R&D for materials processing in space, it will be helpful to examine the factors influencing the profitability of new products as they are introduced into the market. Section 7.2 discussed the evolution of a product from idea conception to commercial production. Each product or process might prove to be slightly different; but, in the normal development, each product life-cycle activity has a "natural" gestation period as shown by point T_n in Exhibit 7-8. Under a given set of conditions, any expansion of this time scale causes the total activity cost to increase and likewise efforts to compress the time scale can only be achieved by an additional allocation of funds. Construction industries are very familiar with this situation and they have sophisticated models to minimize costs.

Exhibit 7-8 shows that there is a minimum activity time which can be achieved regardless of how much money is spent. These time segments become important when one recognizes that many industries have a payback period requirement of 1 to 3 years. In fact, it is unusual in today's market for a manufacturing industry to have a payback period greater than 5 years even with a very high return on investment. One of the reasons is the relatively short production (profitability) phase of new products.

The product life-cycle time is divided into three phases in the Financial Evaluation Model. This model could be more finely divided if one wanted to study a particular aspect of the product life cycle, but this division is adequate to demonstrate some of the difficulties of getting private industry involved in R&D related to materials processing in space.

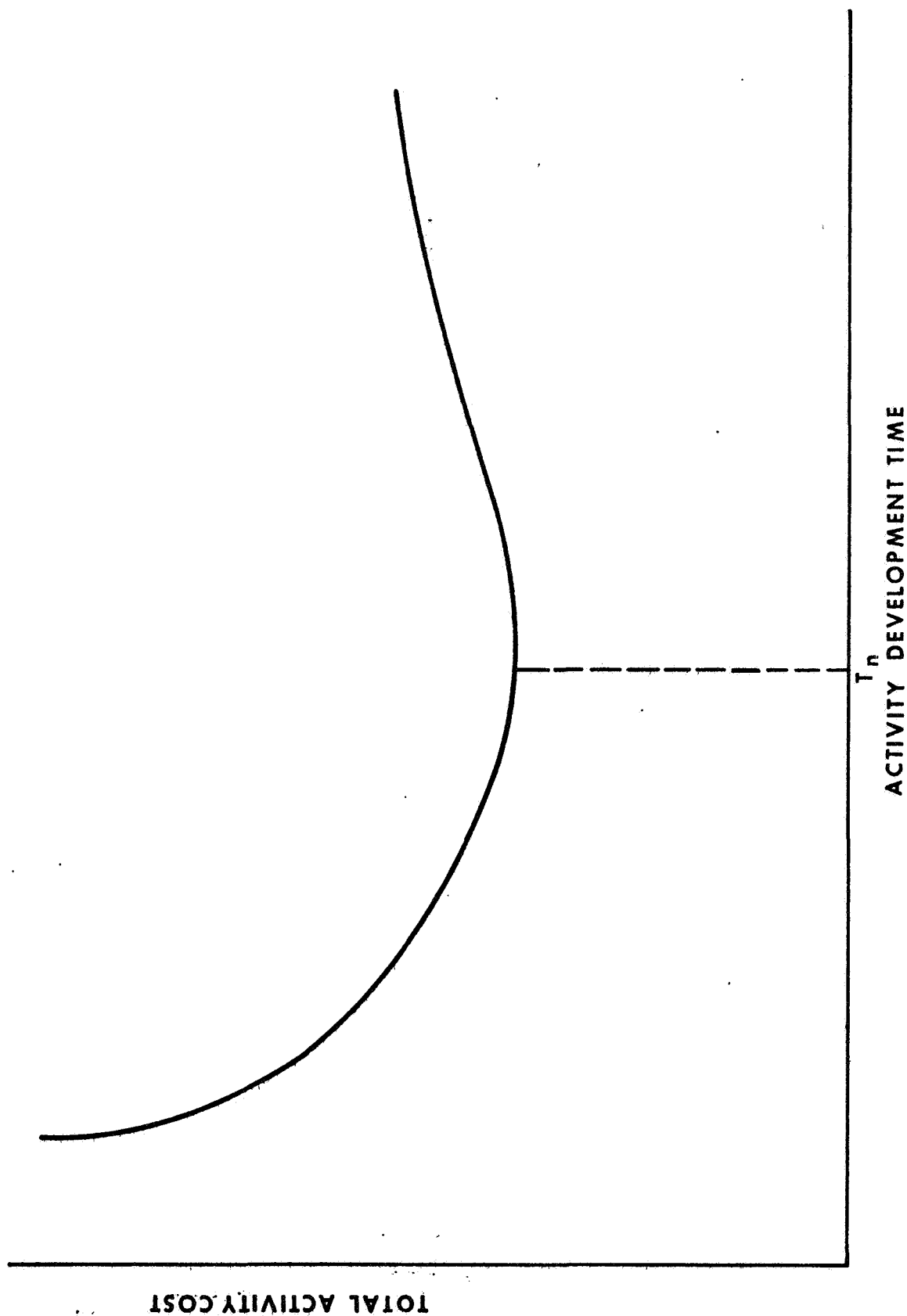
The following definitions are used in the model:

T_{FD} -- Time of Fundamental Discovery
 T_{PP} -- Time of Pilot Plant Production
 T_{CE} -- Time of Competitive Entry
 T_{PS} -- Time of Production Stopped
 $\Delta R\&D = T_{PP} - T_{FD}$ -- R&D phase for the new product
 $\Delta PROD = T_{CE} - T_{PP}$ -- Production phase or the time of reasonable profitability
 $\Delta COMP = T_{PS} - T_{CE}$ -- Competitive phase or the time of competition from new products

Some characteristics of each phase might be as follows:

$\Delta R\&D$ -- This phase does not necessarily begin with the initial idea evolution, but begins at the point where money is invested directly on the process or product. This phase is characterized by negative cash flow and is of major concern because when this phase becomes extended, the investment must be recovered at a faster rate to show any profitability. Finally, this phase comes to an end as pilot plant production demonstrates commercial feasibility and market studies show evidence of profitability.

Exhibit 7-8

ACTIVITY COST/TIME MODEL

Δ PROD -- This phase is of extreme interest to an individual or an industrial firm because it is characterized by positive cash flow which is the prime mover for industry involvement. The shorter this phase becomes, the faster the money must be recovered.

Δ COMP -- This phase is characterized by the introduction of new products, by the termination of patents and the expiration of fads. The competitive entry can come from within the firm or by other firms, but this phase becomes evident by low or marginal profits. Close examination might show that it is time to deploy resources into other ventures. Finally, at time T_{PS} production should be terminated because it is no longer profitable.

At the beginning of the industrial revolution, a product might have a life cycle as shown in the top line of Exhibit 7-9. The R&D phase would be relatively short followed by a long-term production phase and, finally, a phase-out caused by new products, new ideas or simply new fads. As industry becomes more complex, two unfavorable things begin to happen: One, the R&D phase becomes longer, and two, the profitability phase becomes shorter. Both of these things have a deleterious effect on company investments. As R&D becomes more complex, the R&D phase becomes longer and the negative cash flow problem becomes a critical factor. Then, as the production phase becomes shorter, the money must be recovered at a much faster rate. The lower line of Exhibit 7-9 shows the latter condition.

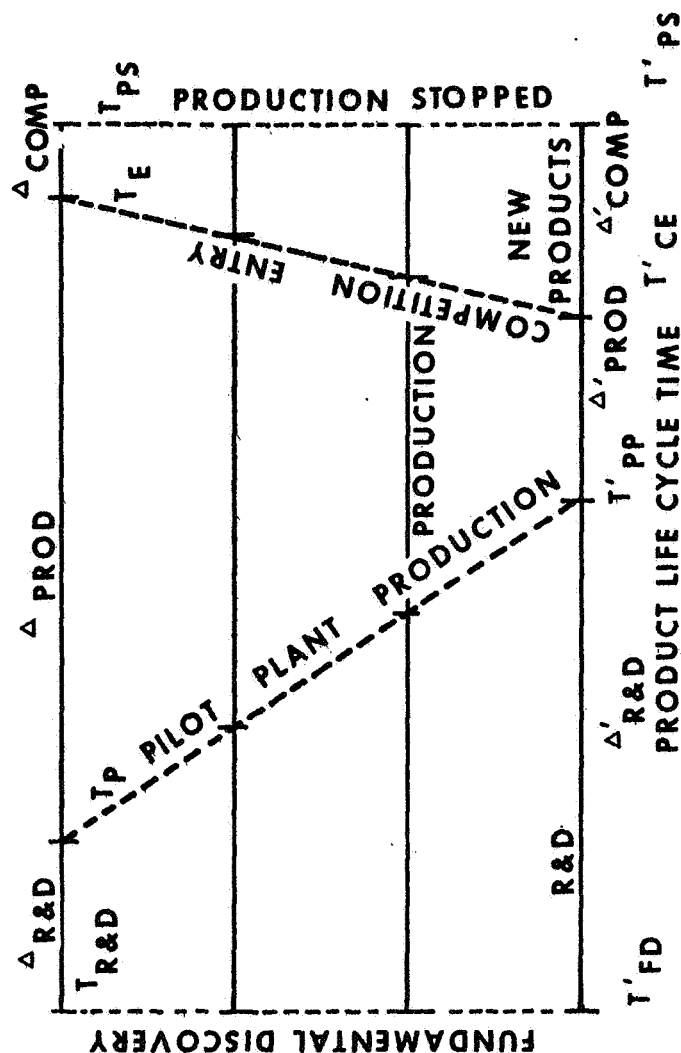
Exhibit 7-10 shows the Financial Evaluation Model. It is related to Exhibit 7-9 with compatible nomenclature. One major parameter of concern to industry is the Return on Investment (ROI) and this report will address this question of "required" ROI before a company will invest its own money.

As demonstrated in the Exhibit 7-10, as the R&D phase increases (Δ R&D), a company requires a higher return on their investment because the money is invested for a longer period of time. Another factor that has a strong influence is the ratio of Δ PROD/ Δ COMP. This parameter is governed, to a large extent, by the amount of control a company is able to retain over its product. If the assumption is made that total product life cycle ($T_{PS} - T_{FD}$) remains constant for a given product, Δ PROD becomes smaller as Δ COMP increases for constant Δ R&D. More funds could be attracted for long R&D phase ventures, such as materials processing in space, if some means could be provided whereby a company could have more control over the results of its R&D and the ideas generated from those efforts.

Another point of interest from Exhibit 7-10 is that at some level of R&D time (Δ R&D), private industry will not invest at all. The risk is too great, the payback period is too long (if achieved at all) and, in general, the burdens far exceed the benefits.

Exhibit 7-9

COMPARATIVE PRODUCT LIFE CYCLES



SYMBOL

T_{FD}

T_{PP}

T_{CE}

T_{PS}

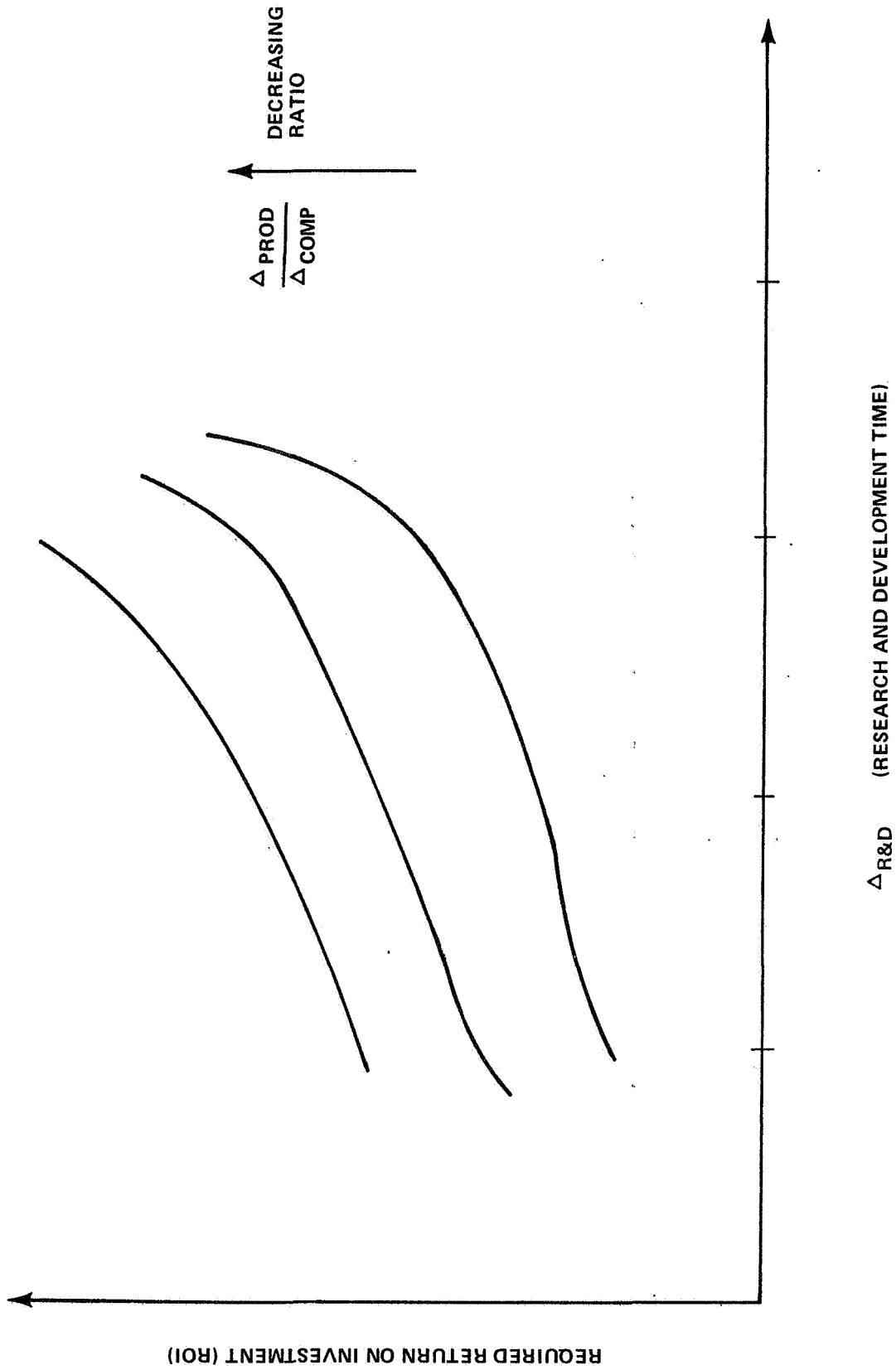
$$\Delta R\&D = T_{PP} - T_{FD}$$

$$\Delta PROD = T_{CE} - T_{PP}$$

$$\Delta COMP = T_{PS} - T_{CE}$$

Exhibit 7-10

FINANCIAL EVALUATION MODEL DEVELOPMENT TIME/ROI TRADE-OFF



7.4.2 ALTERNATIVES

There are two basic sources of funds, public and private. There are, of course, an infinite number of combinations and different incentive plans can be provided for all of these.

7.4.2.1 PUBLIC

The recent published literature has begun to address the problem of R&D incentives and the role of the government in the process. The central question is, "Should the government be involved in R&D which benefits private enterprise?" Addressing this question, the 1972 Economic Report of the President's Council of Economic Advisors said:

"...Government has an appropriate role in R&D even when its results will not be incorporated in Government purchases, because private firms would under-invest in R&D for goods normally purchased by the private sector. Although an investment in R&D may produce benefits exceeding its costs from the viewpoint of society as a whole, a firm considering the investment may not be able to translate enough of these benefits into profits on its own products to justify the investment. This is because the knowledge which is the main product of R&D can usually be readily acquired by others who will compete away at least part of the benefits from the original developer. This is particularly true of basic research where the output frequently occurs in the first instance not as a marketable product, but rather as an advance in basic knowledge that can subsequently be used in applied research and development by a wide and often unforeseeable range of firms" [Davitt - 76].

Language similar in tone also appeared in the President's Message on Science and Technology, delivered March 16, 1972, in which the nature of the proposed U. S. Government initiatives was detailed.

Eads, an economist, speaks of the government becoming involved in R&D support when the markets fail to adequately perform their job [Eads - 74]. In other words, when direct economic accounting does not project a profit, but when a profit is foreseeable when the externalities are considered, government R&D support is appropriate. Eads cites the large government role in the development of the commercial aircraft industry through support of military R&D and subsidies to the airlines. He concludes with an observation on whether the imperfect market or the imperfect bureaucrat should be used to determine what R&D to pursue.

Certainly, the source of R&D funding remains an open question. Business Week reported the business expenditures for R&D in 1976. A survey of 598 companies covering 99 percent of all private R&D found a total expenditure of \$16.2 billion. That figure represents

35 percent of the \$47.8 billion in profits earned by those firms. On the other hand, in the same period the Federal Government's R&D spending was \$23.6 billion. Of the government's share, about 70 percent is performed by contractors and private industry [Business Week - 77-2]. Thus, the government has the major input in determining what R&D is performed in both its own and the private sector.

One can argue whether the government should have such a large role in determining what R&D is to be conducted. Certainly, the government should exercise direct control over R&D for public sector goods and services, such as military hardware and space exploration. This question becomes more difficult when the primary R&D benefactor is the private sector rather than the public sector. Materials processing in space might well be in this latter category. One rationale for government investments in such R&D is the social desirability of such activities. For example, the health-related spinoffs from the Apollo program may well have paid its original R&D cost. In addition, private industry has benefitted from federal R&D spinoffs; e.g., Hewlett-Packard and the development of hand-held calculators.

Some argue that when private industry directly benefits from government-sponsored research, the government should be allowed to recoup its original investment. Windus and Schiffel have reviewed the recoupment policies of 6 countries outside the U. S. [Windus - 76]. They conclude that "it is not currently possible to tell whether or not a recoupment policy would be worthwhile." The administration of such a policy is one major problem. How are risks, costs and profits to be shared by the government and the private investor? One should also note that the current federal corporate income tax effectively recoups 50 percent of any R&D generated profit and covers 50 percent of any loss.

7.4.2.2 PRIVATE

The private sector is a definite source of funding for new products that need space as a processing environment either for one step or complete sequencing. Very stringent requirements must be met to induce support of industrial firms to invest development monies. Although each company has its own specific set of criteria, it seems realistic to assume that the criteria used by Gould, Inc. [Business Week - 77], and elaborated upon by Steg [Steg - 74], is representative of the commercial sector. The criteria are:

"Development to market introduction should take no longer than 3 to 5 years; the total market of the product should run \$50M and be growing at least 15 percent a year; the product must be capable of producing a pre-tax return on 30 percent of sales and 40 percent on investment, and it must establish Gould as either a technical or market leader in a product field."

Beyond these requirements, there also exists several major problems that must be overcome if industrial concerns are to become active participants in the space industrialization field. These include: Industrial security, costs and charges of the transportation system, and a well-coordinated system to facilitate planning, schedule adoption, decision making and priority development. These areas have been well addressed in the Beneficial Uses of Space Study [Steg - 74] in regard to the integration of payloads into Spacelab.

Consider the recommendations of Harry G. Colwell, vice president of Chase Manhattan Bank:

"Chase Manhattan has substantial loans outstanding to sizable portions of the aerospace industry. Colwell proposed these remedies to ease the capital crisis:

- Increased inducements for personal savings.
- Realistic depreciation allowances.
- Preferential tax treatment for retained earnings used for investment.
- Lower taxes on capital gains.
- A stabilized monetary and fiscal policy for the economy.
- Elimination of unnecessary controls, agencies, and government regulations.

[Astronautics and Aeronautics - 77]

7.4.3 TRADEOFF ANALYSIS

One factor very evident is that traditional money managers are not willing to invest large sums in long payback ventures under the current financing schemes [Old - 72].

Even small companies that are eligible for government loans find the risk too high. It appears that a new financial model needs to be developed for ventures in space. Two such "preliminary" models are suggested here:

1. With a substantial government funding source, the U. S. Government would see a project through pilot plant production (Exhibits 7-2 and 7-3) and new/different legal constraints need to be applied. The Federal Government currently works in conjunction with state governments as a substantial financial contributor and a similar model could work with the materials processing in space industry.

2. A second type of model could permit certain "medium" size business loans to carry a product through to commercial production.

If the firm makes a profitable venture out of this effort, then the money would be repaid according to a formula; if the venture goes bankrupt, the loan is forgiven and all benefits would default to the government.

7.4.4 RECOMMENDATIONS

Specific recommendations follow in the R&D Plan Section 7.5.

7.5 THE R&D PLAN

The extension of U. S. technology is frequently feared by other nations despite the long record of the U. S. to transfer technology to developing nations. The capability of the Space Shuttle to transport men and materials to and from space offers the U. S. the opportunity to lead the world in a major technological advancement. As discussed in this chapter, there is a serious need to develop a coordinated R&D plan for materials processing in space. That plan must include the ground-based R&D facilities. Only the ground-based R&D facilities have been considered in the discussion of this chapter.

In this section the assumptions are reviewed and specific recommendations are made for the R&D plan. The following assumptions are made:

- ° The Space Shuttle and Spacelab will be a viable space transportation and experimentation system during the 1980's.
- ° Materials processing in space has significant potential benefit to mankind.
- ° The government has a legitimate role in the sponsorship of R&D.
- ° Private industry has the right and duty to take reasonable risks and reap the rewards or accept the burdens associated with the eventual outcome.
- ° When projects are not clearly appropriate for either government or industry separately, a government/private industry cooperation is desirable and can be worked out.
- ° International cooperation can be supported without yielding competitive trade advantages.
- ° Society gains significant long-term benefit from government-sponsored R&D.
- ° The government should not compete either directly or through excessive regulations in areas where private industry is willing to assume the risks involved.

With the previous assumptions in mind, recommendations will be made for both near and long term. The recommendations will be made based on ideas developed in this chapter along with data reported throughout this report. Each major recommendation is preceded by the appropriate supporting material or references or by indicating the barrier to progress which must be removed to make commercial materials processing in space a reality.

7.5.1 NEAR TERM ACTION

It is apparent that private industry will not commit any significant resources to materials processing in space [O'Brien - 77] until its feasibility has been clearly demonstrated and the space transportation system has been proven reliable. It is also apparent that a vast number of space environment properties, processes and products should be investigated for potential materials processing in space application. All the associated R&D requires a significant commitment of resources for its timely completion and NASA's budget of \$6 million for this effort is inadequate to serve as a catalyst for commercially viable materials processing in space in the foreseeable future. Even with the expected doubling of the materials processing R&D budget in the next five years it will not be sufficient to provide the needed effort.

RECOMMENDATION: The budget for materials processing in space research and development should be put on a par with the cost of flying the experiments in the Space Shuttle/Spacelab orbiter. Assuming that about 6 flights per year will be dedicated to materials processing in space and a flight cost of \$20 million, a materials processing in space R&D budget of \$120 million per year seems appropriate for the decade of the 80's. A gradual budget buildup from the current level should occur between now and 1980 or the beginning of the Space Shuttle era.

This chapter has discussed the product life cycle and the structure and financing of the associated R&D. It appears evident that materials processing in space has yet to reach the point of fundamental discovery and, hence, the current emphasis must be on basic research. Also, private industry cannot be expected to fund this basic research because of the risk and long payback period involved.

RECOMMENDATION: A single ground-based research laboratory to support materials processing in space should be established. A matrix form of organization should be used for the laboratory (See Exhibit 7-11). The matrix organization crosses work in the areas of space properties with the potential materials processing in space application areas. The matrix organization provides a Scientific

Exhibit 7-11

MATRIX ORGANIZATION FOR GROUND-BASED MATERIALS
PROCESSING IN SPACE R&D LABORATORY

Potential Materials Processing in Space Applications	SPACE PROPERTIES				Industrial Utilization Advisory Panels
	Micro-g	Hard Vacuum	Low Vibration		
Bio-medical	X	X	X		X
Metals	X	X	X		X
Non-metallic Materials					
Glasses	X	X	X		X
Crystals	X	X	X		X
...					
Special Products					
Glass Beads	X	X	X		X
...					
Scientific Advisory Panels	X	X	X		R&D Planning Advisory Panel

Advisory Panel for each of the space properties areas. These panels will consist of leading researchers in the particular field. Industrial Utilization Advisory Panels will be formed for each potential materials processing in space application. The members of these panels will be from a level of industrial vice presidents for R&D. The chairpersons of each panel will form the R&D planning advisory panel for the laboratory.

Applied research should be initiated as fundamental discoveries are made. This may dramatically expand the effort in certain areas.

RECOMMENDATION: Rather than increasing the size of the single ground-based laboratory, the possibility of establishing specific mission laboratories, each encompassing one row or one column of the matrix on Exhibit 7-11, should be considered. An evolution of these specific mission laboratories is envisioned to conduct applied research and initiate product development. Heavy government financing of the specific mission laboratories is initially expected. Some support from foreign governments and private industry might be expected for some applied research laboratories. Generally, product development and production activities should be left to private industry. However, initially, the government may have an appropriate role in demonstrating production feasibility to private industry.

Idea ownership and equitable rewarding of the innovator are critical to technological progress.

RECOMMENDATION: All discoveries made by the staff of the laboratories are to be considered in the public domain and made available free for domestic use. Industrial or academic fellows working at the laboratories would be permitted limited exclusive rights to their discoveries. These rights would hold only for a relatively short time period -- say 5 years -- to encourage rapid development and timely entry of competition. Private industries wishing to use the laboratories on an exclusive basis may do so by entering into a full cost lease arrangement. The laboratories shall use the revenues generated from such leases in excess of expenses to obtain additional equipment.

The current trend in government R&D towards contract R&D has left the in-house staff of many agencies without sufficient technical

expertise to adequately plan and evaluate the contractor's work.

RECOMMENDATION: At least 50 percent of the laboratories' work should be in-house. Contracts should be employed to smooth effort level transitions and for short duration activities. Academic researchers should be supported as a means of training new program personnel.

The current NASA structure cannot effectively service a broad range of space users.

RECOMMENDATION: A Space Coordination Center should be established within NASA or as a separate agency to perform these missions:

- ° Serve as a central source of space information,
- ° Allocate space flight resources, and
- ° Administer the "New-User Special" incentive program for new space users.

7.5.2 LONG TERM OUTLOOK

After the maturation of materials processing in space industry, the government may continue to play an active role in research. A single laboratory for basic research and specific mission laboratories for applied research would seem to remain a viable option. Private industry may have also entered the research activity, but depends on the laboratories as a point of coordination and knowledge exchange. The Space Coordination Center will remain the primary interface between space users and the space transportation system.

The government's research effort should continue at a spending rate equal to 50 percent of the tax revenues generated from materials processing in space profits.

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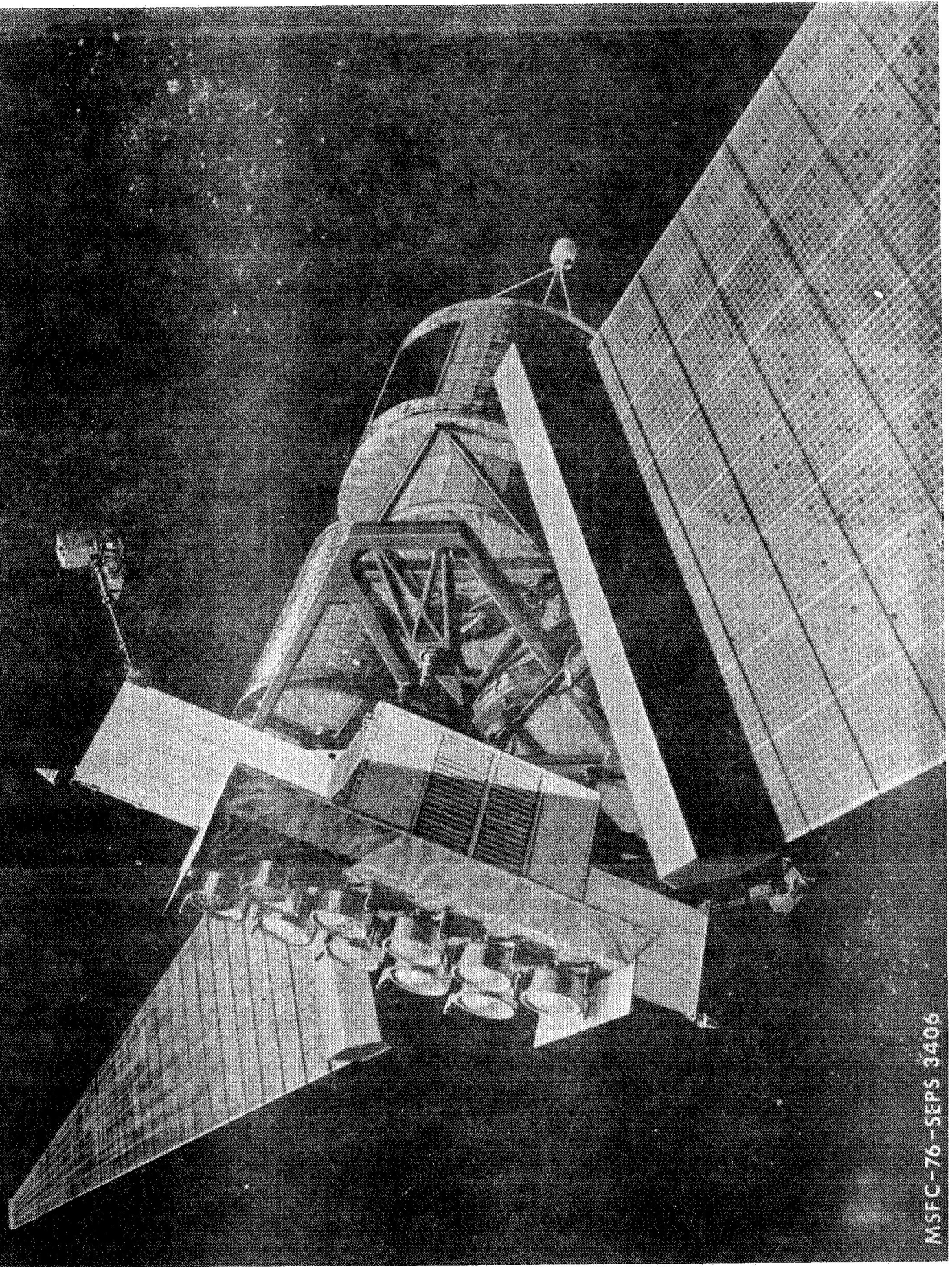
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SOLAR ELECTRIC PROPULSION STAGE



MSFC-76-SEPS 3406

CHAPTER 8

SOCIO-POLITICAL CONSIDERATION

8.1 INTRODUCTION

The goal here is to develop a proper socio-political climate for materials processing in space. This study was bound by these controls (constraints and criteria):

- ° Present trend in socio-political systems and space agreements
- ° Present world population growth rate
- ° Present U. S. quality-of-life expectations
- ° Present NASA space program awareness as minimum
- ° Incremental growth NASA funding level for materials processing

These areas of concern were identified:

- ° Natural resources and the human environment
- ° Human resources accounting and social effects
- ° Legal implications, and
- ° Public relations (PR)

Five requirements and their respective alternatives within these areas were established:

1. Environmental considerations

- ° Environmental impact matrix (EIM)
- ° Environmental impact statement (EIS)
- ° Natural resources accounting
- ° Combination

2. Human resources accounting
 - ° Expense
 - ° Capital asset
3. Adequate legal structure
 - ° United Nations treaties
 - ° Multi-national corporation influence
 - ° International/bilateral talks
 - ° Combination
4. Quality-of-life considerations
 - ° Technology assessment by OTA
 - ° General public survey
 - ° Low-funding level study
 - ° Delphi-computer conference
 - ° Social impact assessment (SIA)
5. Space program awareness
 - ° Establishment of a national space goal
 - ° Social impact assessment (SIA)
 - ° Additional advisory boards to NASA and identification of the materials processing program with a national goal

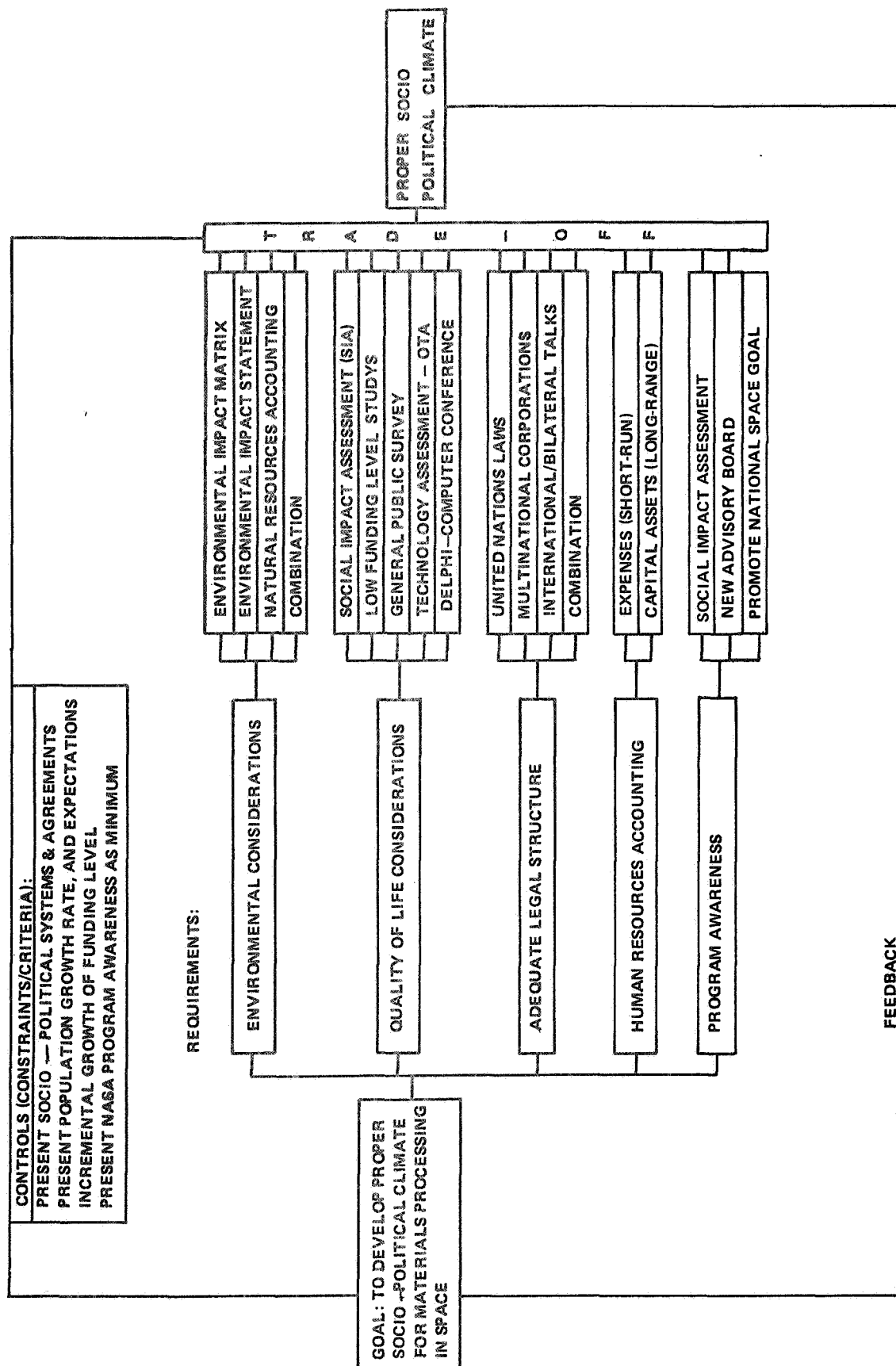
Exhibit 8-1 shows the subsystem diagram for the socio-political study.

A general discussion of the environmental problems that may confront NASA as they develop space is presented using the concept of environmental impact matrix (EIM). Specific environmental problem areas with short- and long-range implications are defined and explored. Several goals are delineated for NASA.

The question of whether to treat human resources as capital assets or as expenses is addressed. Modern and conventional accounting systems are reviewed for this purpose. Short- and long-term effects, goals and benefits are examined. The new concept of human resources accounting is explained.

Exhibit 8-1

SOCIO-POLITICAL SUBSYSTEM DIAGRAM



The current state of space laws and treaties is reviewed in order to examine the alternatives to establishing an adequate legal structure.

To prepare the public for materials processing in space, consideration is given to quality-of-life changes. Questions about quality of life surface in many cases where Federal money is spent for high technology endeavors. People have the right and want to know whether tax dollars will bring social benefits. Planning for these inquiries is addressed.

Finally, this chapter examines some alternatives in space program awareness. Part of the NASA mission is to keep the public well informed about its programs. A recommendation is made for improving this awareness.

8.2 ENVIRONMENTAL CONSIDERATIONS

8.2.1 INTRODUCTION

The present and the future require a sound assessment of environmental risks and benefits and a clear analysis of alternative solutions. The formulation of public policy, environmental planning and the development of a basis for public decision making will come from this assessment; the analysis of alternatives and their relative costs; and by inter-disciplinary studies of the interaction of environmental sciences (Exhibit 8-2).

The National Environmental Policy Act was enacted in 1969 because of the mounting pressure from concerned citizens and environmental groups. As a result, "every recommendation or report on proposals for legislation and other federal actions significantly affecting the quality of the human environment" [NEPA - 69] require an Environmental Impact Assessment.

The early research and development in material processing in space and other facets of space industrialization will be funded by the Federal Government through NASA; thus, an Environmental Impact Statement (EIS) will be necessary.

The Design Group considered: (1) the development of an EIS for material processing in space, (2) the development of an Environmental Impact Matrix (EIM) and (3) a related Natural Resource Accounting. The EIM was chosen as the appropriate alternative to study and complete because of the time limitations for completing a useful EIS (Exhibit 8-3) and a group-imposed constraint to only consider terrestrial materials. The EIM is usually a necessary prerequisite for the EIS.

A Natural Resource Accounting study is necessary in the future. Both the terrestrial and non-terrestrial resources should be inventoried. Preliminary studies indicate the need to start utilizing non-terrestrial resources for two reasons -- less impact on the environment and the decreasing supply of some resources.

Exhibit 8-2

INTERACTION OF ENVIRONMENTAL SCIENCES

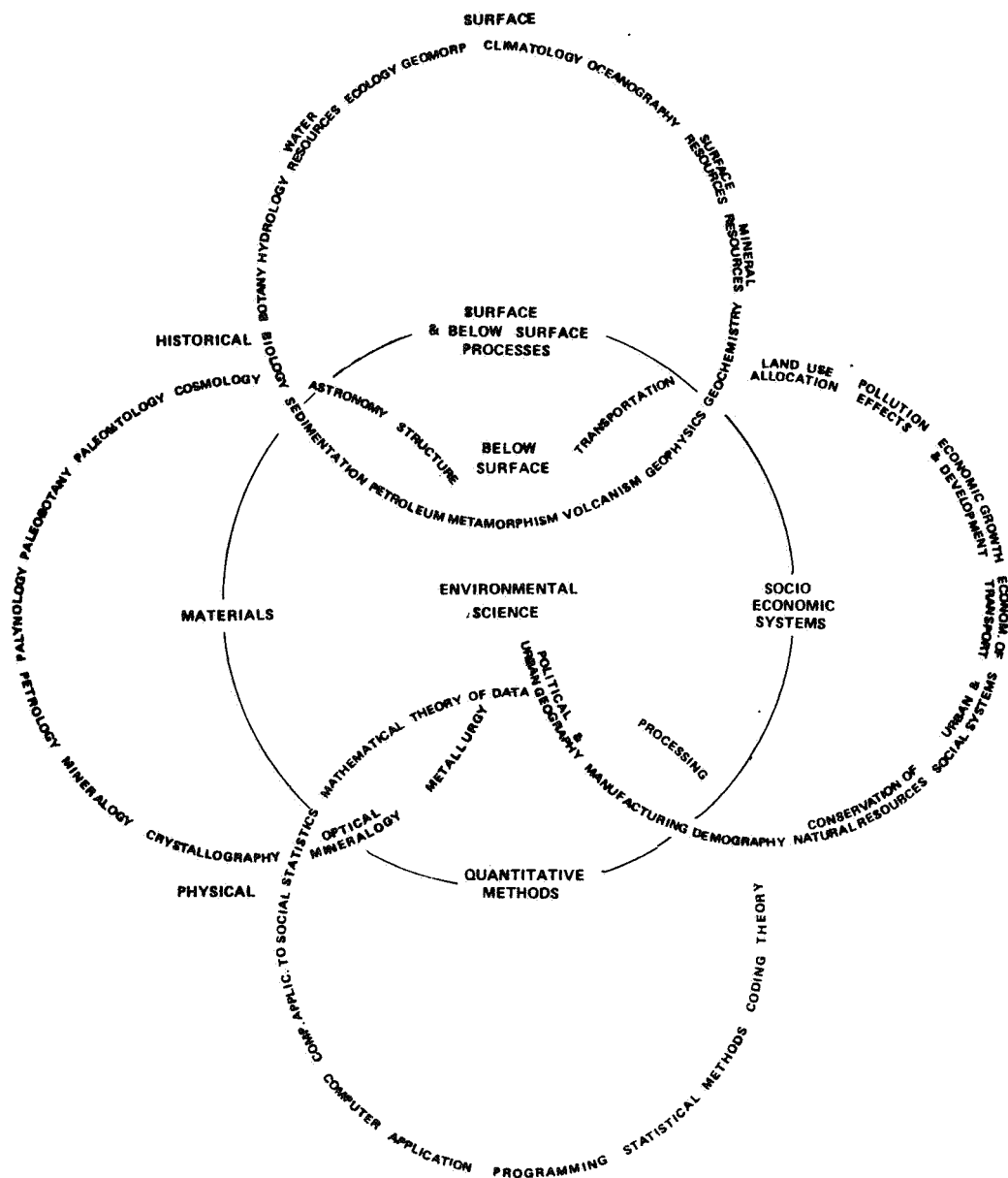


Exhibit 8-3

ENVIRONMENTAL IMPACT STATEMENT
Sections Which Must be IncludedA. Phases

1. Development of Guidelines

The establishment of formats and procedures for the preparation of statements and review procedures, as well as guidelines for holding public hearings [AEC-73; E.P.A.-73; US65-74].

2. Justification for Existing Projects

3. Land Use Planning

B. Determination of Need

1. Supported in whole or in part through federal agencies, contracts, grants, subsidies, loans, or other forms of funding assistance .

2. In need of federal license, lease, permit, or certificate.

C. Content

EIS must include [Stover-73; Loran-75]:

1. A description of the proposed action including information and technical data adequate to permit a careful assessment of environmental impact by review agencies.
2. A description of the natural environment of the area affected, including population and growth characteristics.
3. A consideration of the probable impact of the proposed action on the environment, including impact on ecological systems.
4. A description of any probable adverse environmental effects which cannot be avoided.
5. The relationship of the proposed action to land use plans, policies and controls for the affected area.
6. Analysis of studies and descriptions of appropriate alternatives to recommend courses of action. Analysis must be sufficient to accompany the Statement through the review process in order not to foreclose options which might have less detrimental effects.
7. Alternatives to the proposed action.

Exhibit 8-3 (Continued)

8. A concern for the relationship between local, short-term uses of man's environment and the maintenance and enhancement of long-term beneficial uses of the environment, on the grounds that each generation is trustee of the environment for succeeding generations.
9. Irreversible and irretrievable commitments of natural and cultural resources.
10. A cost-benefit analysis or similar study where the Federal policy gains are balanced with the environmental losses.

The following factual data should be included in the items above: (1) Economic parameters, (2) technical problems, (3) socio-political factors and (4) short and long-term environmental impact.

Within the constraining time frame, until year 2000, the impact of materials processing in space on the Earth's environment was determined to be minimal. This program is intimately associated with other space industrialization programs; therefore, the environmental considerations of this study cover all major areas of space industrialization.

8.2.2 ENVIRONMENTAL IMPACT MATRIX

An EIM can be used to present data necessary for the completion of an EIS in two ways: (1) as a preceding step to define the need for further, more extensive, environmental studies to help understand the problem addressed by the EIS, or (2) the presentation of the final data upon completion of the EIS. The first method is used in this report.

To complete the EIM for the space industrialization program, the following steps were completed:

- Identification of the environmental parameters that may be affected.
- Review of the available literature so that a qualitative summary of the effects of this program on the environmental parameters would be assessed.
- Determination of the beneficial and detrimental portions of the environmental impacts taking into account countervailing effects and uncertainty.
- Tabulation of the pros and cons to determine the total effect of the uses on the environment.
- Analysis and summary of the matrix to determine the patterns of environmental impact.

This investigation was essentially qualitative because the relationships between impacts and their effects are complex and not always well understood. A qualitative judgment is better than no attempt to incorporate these complex and difficult parameters. Until recently, resource and other management decisions have been decided almost exclusively in terms of economic efficiency and technical feasibility. Investigators now present the environmental data in a cost-benefit analysis which includes an attempt to quantify subjective elements. This is rarely feasible although incorporation of physical measures can sometimes be accomplished. In such early program evaluation, only qualitative judgments can be obtained.

An EIM for space industrialization was developed (Exhibit 8-4). The environmental problems and components that may be affected by space industrialization are numerous but most of them fall into a

ENVIRONMENTAL IMPACT MATRIX OF SPACE INDUSTRIALIZATION

SPACE INDUSTRIALIZATION USES

			ENERGY				MATERIAL PROCESSING	SERVICES		
			NUCLEAR		SOLAR			COMMUNI- CATION	OBSER- VATION	
			EARTH	SPACE	EARTH	SPACE				
ENVIRONMENTAL PROBLEMS FOR EARTH	NOISE		2/3-1-1/0	4-0-0	2/3-1-0	5-1-1	4-2-2 (ER) 3-0-1 (XR)	3-1-0	2-0-0	
	A I R	TROPO- SPHERE	3-2-17	4-0-1	3-2-2/3	5-0-1 (ER) 3-0-0 (XR)	3-1-1/2	2-0-1	2-0-1	
		STRATO- SPHERE	1-0-1+	3-0-1	1-1-2	4-0-2 (ER) 2-0-0 (XR)	2-0-1	2-0-1	1-0-+	
		IONO- SPHERE	0-0-1+	4-0-1+	0-0-1	5/4-0-3(ER) 2-0-0 (XR)	2-0-1	2-0-1	1-0-+	
	W A T E R	USE OF	1-2-3	1-0-0	1-1-2/3	1-0-+	1-0-1	1-0-1	1-0-+	
		THERMAL	1-1-4/5	1-1-1	1-1-3	1-0-1	1-0-1	1-0-1	1-0-+	
		POLLU- TANTS	3-1-2	3-0-1	1-0-1	1-0-1	1-0-1	1-0-1	1-0-+	
	W A S T E	RADIO- ACTIVE	0-1-3+	0-1-0	1-0-1	0-0-0	0-0-0	0-0-0	0-0-0	
		SOLID	2-1-1	2-1-0	2/3-0-1	1-0-0	1-0-1	1-0-0	1-0-+	
	CLIMATE		1-1-3/4	1-1-0	1-2-3/4	1-1-2	1-0-2	0-0-1	+++	
	C U L T U R A L	POLITICAL		2/3-1-0/2	2-0-1	2-1-1	3-0-1	1-0-1	3-1-2	3-1-3
		LEGAL		3-2-2	4-2-2	2-2-2	4-2-2	3-0-0	2-0-1	2-0-2
		S O C I A L	PHYSCH	4-2-1	4-1-4	3-1-0	3-1-+	2-0-1	1-0-0	2-0-2
			CRIME	2-1-1	2-0-0	3-1-1	1-0-0	1-0-0	+++	0-0-0
		LAND USE		3-1-2	3-0-+	4-2-4	4-0-+ (ER) 1-0-+ (XR)	2-0-0	1-0-+	1-+-+

Exhibit 8-4 (Continued)

LEGEND

MEANING OF THE NUMBER LOCATION

1st # (CONSTRUCTION PERIOD) — 2nd # (ONLINE) — 3rd # (AVERAGE USE)

BREAKDOWN OF THE NUMBER VALUES

- 5 — SERIOUS ENVIRONMENTAL PROBLEM/S**
- 3 — MODERATE POSSIBILITY OF AN ENVIRONMENTAL PROBLEM/S**
- 1 — NOT A SERIOUS ENVIRONMENTAL PROBLEM**
- 0 — NO DETRIMENTAL OR POSITIVE EFFECT/S OVERRIDE NEGATIVE EFFECTS.**
- + — POSITIVE AFFECT**
- ER EARTH RESOURCES**
- XR EXTRA TERRESTRIAL RESOURCES**

limited number of broad categories: (1) noise, (2) air, (3) water, (4) solid waste, (5) climate and (6) cultural and social implications. The series of environmental problems and components are listed on the vertical axis, while the areas of space industrialization that are to be evaluated are listed on the horizontal axis.

In view of the designs and assumptions made in this study, the areas of space industrialization were compared in terms of each potential impact and ranked. A rating of "0" denotes no impact, "1" denotes a slightly adverse impact, a "5" denotes a severe, large impact potential and a "+" indicates a potential positive impact.

Time is represented within the matrix by completing a ranking for the following three time periods: (1) construction period, (2) construction completed and (3) facility being used at average capacity. This time frame method is illustrated in Exhibit 8-5. This is primarily intended to pinpoint areas which need further investigation and research. Although a considerable amount of library research was completed for this study and the author is knowledgeable about the environmental problems investigated, the actual rankings are controversial and may vary by ± 1 . Even so, those entries of 4 or 5 indicate areas requiring investigation and those with entries of 3 also need further study.

After an introductory section discussing the general environmental problems that may occur due to space industrialization, each use item will be discussed in the order illustrated in Exhibit 8-4 -- energy, material processing and services.

8.2.3 GENERAL ENVIRONMENTAL PROBLEM DISCOVERIES

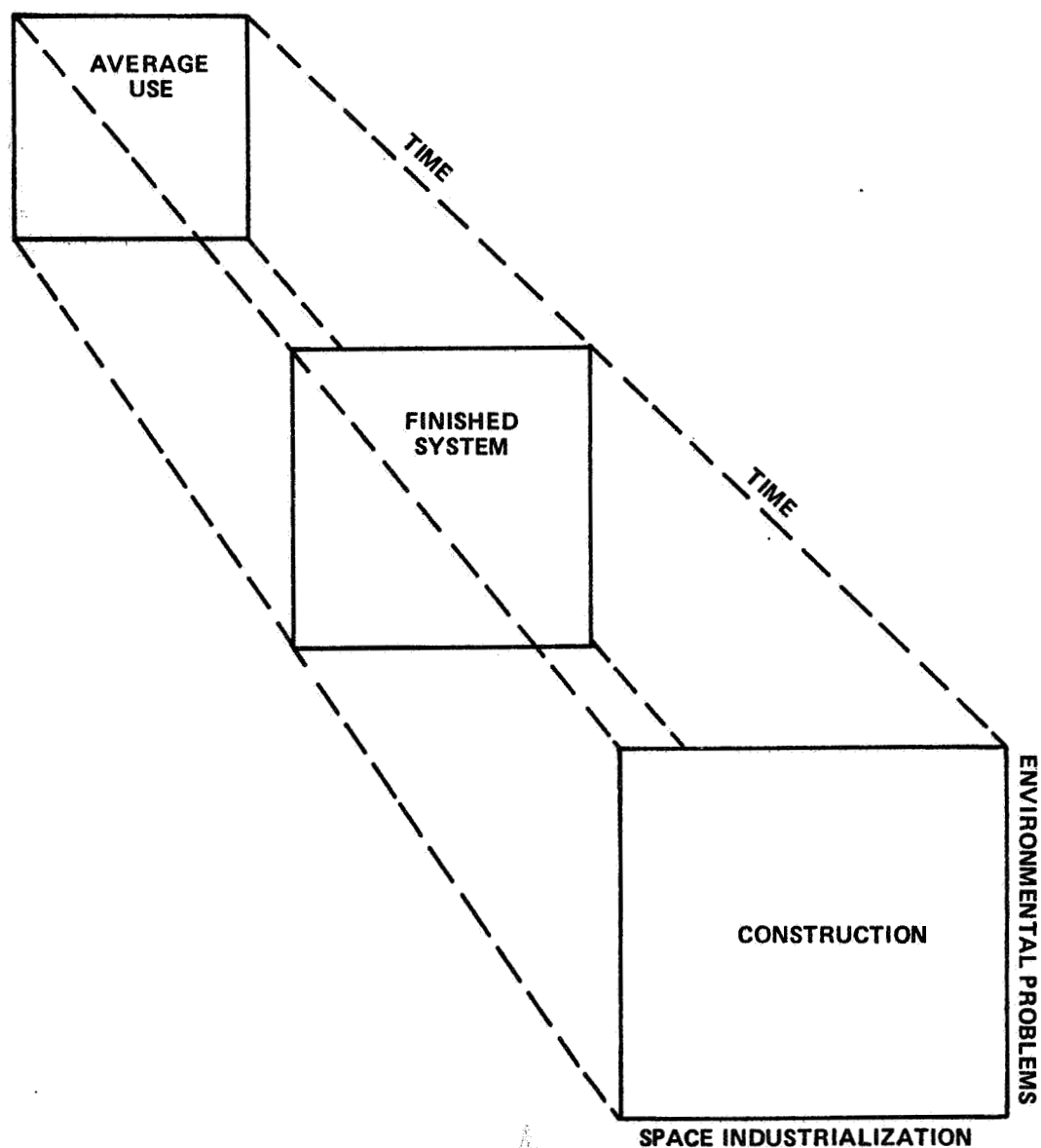
There are numerous environmental problem areas. All of them are influenced by the space program, however, as Exhibit 8-4 indicates, the climatic and atmospheric problems have the potential to be the most seriously and directly affected. Principally, the effects will be: changes in quantity of particular elements; changes in air composition; changes in the passage of solar and terrestrial radiation; changes in the weather elements, particularly temperature and frontal migration; heat budget changes, and local noise. Surface changes in the hydrosphere and upper lithosphere may occur; i.e., increased temperature of water bodies and land-use problems which cause changes in albedo, atmosphere motion and particle content. The other serious problems are associated with cultural interactions.

8.2.3.1 CLIMATE CHANGES

There is little doubt that there has been an effect, worldwide as well as locally, on climate by human technological advances, although it is still difficult to say just how much or what has caused it [SMIC - 71]. Our influence on the climate to this date

Exhibit 8-5

SPACE INDUSTRIALIZATION TIME FRAME



has probably been small. The real concern should be that we could change the climate in a larger way and begin to match nature's forces with our own. A 4 percent per year energy growth rate will put 1 percent of the absorbed solar intensity into the Earth's atmosphere in 130 years and 17.5 years later will put in 2 percent. Our activities will cause us to reach the 100 percent level 120 years later (2200 A.D.) [Kellog - 72]. There now is a cooling trend occurring. If the trend continues (-0.3°C during the last 30 years [Larson - 76]) for 200 to 300 years, continental ice masses could develop and advance across the temperate areas again. However, if energy production continues to increase at the present rate the cooling trend will disappear and a drastic upturn in the Earth's temperature will occur. No matter which trend, cooling or warming, it must be realized that even as small a systematic mean planetary temperature change as 0.27°C [Penner - 76] may produce global climatic changes. Vegetation, specifically crops, will be affected by the north/south movement of the limiting temperature patterns, by the changes in precipitation and by changing wind direction and intensity. There may also be the initiation of disastrous feedback mechanisms. Small, local glaciers may melt lowering the surface albedo which in turn would cause a greater absorption of solar radiation. This increased temperature would be fed back to melt more ice, which could raise sea levels and thus drown coastal cities. We cannot accurately predict what changes will occur in the Earth's climate due to human activities, much less space industrialization, but the distinct possibility that it could occur warrants every effort to understand the mechanisms that govern climate and its change.

8.2.3.2 ATMOSPHERIC CHANGES

Three principal environmental problems are associated with atmospheric change: (1) ozone reduction in the stratosphere, (2) increased pollution in the stratosphere and ionosphere and (3) increased pollution in the troposphere.

1. Ozone Reduction

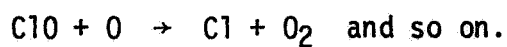
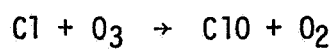
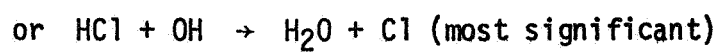
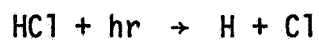
The extent to which the atmospheric ozone may be changed by natural and human events is uncertain, but the possible mechanisms causing the change are not. Ozone can be affected by aircraft or space vehicles [Cunnold - 74-4; Johnston - 71; Westenberg - 72], fluorocarbons [Molina - 74-2], atmospheric nuclear weapon tests [Johnston - 77] and by natural events such as volcanic effluents and solar proton activity.

Space industrialization would affect the ozone layer by the passage of space vehicles through the stratosphere and the attendant release of oxides of nitrogen and hydrogen chloride which would react with ozone to reduce the quantity of ozone (Exhibit 8-6) [Whitten -

Exhibit 8-6

REACTION OF POLLUTANTS AND OZONE IN THE STRATOSPHERE

1. Hydrogen chloride



2. Oxides of nitrogen



75; Wong - 74-2]. A reduction in the amount of ozone would allow more ultraviolet sunlight to reach the surface of the Earth which may cause genetic defects and an increase in skin cancer occurrences.

2. Increased Pollution in the Stratosphere and Ionosphere

The two primary pollutants not associated with ozone breakdown are aerosol/particulates and water vapor. The normal stratospheric aerosol/particulates and water vapor content is very low. If aerosol/particulates and moisture are transported into the stratosphere by space vehicles it could modify the temperature distribution of the atmosphere through the greenhouse effect and increase the clouds in the lower stratosphere. It has been estimated that if the water vapor in the whole stratosphere were doubled, the greenhouse effect would raise the temperature of the air near the Earth's surface about 0.5°C while tending to cool the stratosphere [Manabe - 67].

3. Increased Pollution in the Troposphere

The stratosphere and troposphere are differentiated in this section and in Exhibit 8-4 because the tropopause, except in the region of the tropopause break zone and in the vicinity of severe storms, is generally considered to be a rather effective barrier to the interchange of air between the troposphere and stratosphere. Also, any air which passes from the troposphere to the stratosphere must pass through a very cold region and the moisture would precipitate.

The increase in tropospheric pollution would come from space vehicle launches and the use of energy for the development of resources and the manufacturing necessary for the space program. Increases in all compositional types of pollution will result, primarily at the local and regional levels. The energy use will be most detrimental at first, until the number of launches increases greatly. It will be difficult to conform to the United States primary and secondary ambient air quality standards (Exhibit 8-7) and the other possible laws governing significant deterioration alternatives. This is especially true if fossil fuels continue to be the main source of energy. This and the stratospheric pollution problem are very serious because of the amount of time pollutants remain unaltered in the environment (Exhibit 8-8).

8.2.4 ENERGY PRODUCTION

Exhibit 8-4 examines and compares the use of two means of energy production, nuclear and solar; considered at two different locations, terrestrial and orbital. These particular energy options were examined because other alternatives do not directly associate with space industrialization, they are environmentally damaging, they have limited potential due to lack of supply or they are not feasible within the given time frame. Data is sufficient to indicate the serious nature of the energy problem (Exhibit 8-9). High-grade petroleum and natural

Exhibit 8-7

SULFUR DIOXIDE AND SUSPENDED PARTICULATE MATTER

U.S.A. PRIMARY AND SECONDARY AMBIENT AIR QUALITY STANDARDS

Pollutant	Type of standard	Averaging time	Frequency parameter	Concentration ($\mu\text{g}/\text{m}^3$)	Concentration (ppm)
Carbon monoxide	Primary and secondary	1 hr	Annual maximum ^a	40,000	35
		8 hr	Annual maximum	10,000	9
Hydrocarbon (nonmethane)	Primary and secondary	3 hr	Annual maximum	160 ^b	0.24 ^b
		(6 to 9 AM)			
Nitrogen dioxide	Primary and secondary	1 yr	Arithmetic mean	100	0.05
Photochemical oxidants	Primary and secondary	1 hr	Annual maximum	100	0.08
Particulate matter	Primary	24 hr	Annual maximum	260	—
		24 hr	Annual geometric mean	75	—
	Secondary	24 hr	Annual maximum	150	—
		24 hr	Annual geometric mean	60 ^c	—
Sulfur dioxide	Primary	24 hr	Annual maximum	365	0.14
		1 yr	Arithmetic mean	80	0.03
	Secondary	3 hr	Annual maximum	1300	0.5

^a Not to be exceeded more than once per year.

^b As a guide to devising implementation plans for achieving oxidant standards.

^c As a guide to be used in assessing implementation plans for achieving the annual maximum 24-hour standard.

Exhibit 8-8

THE TIME POLLUTANTS REMAIN UNALTERED IN THE ENVIRONMENT

		Pollutant	Location of Development	Amount of Time
Atmosphere		Carbon dioxide	Ground level (G1) Stratosphere (S)	~ year > 2 years
		Carbon monoxide	G1 S	~ 2 years > 2 years
		Chlorofluoromethanes	G1 S	40-100 years > 100 years?
		Nitrogen Oxides	G1 S	3-4 days 1-2 years
		Particulates	G1 S	hours to days 1-2 years
		Sulfur dioxide	G1 S	4-8 days > 2 years
		Water vapor	G1 S	~ 1 week to < month 1-2 years
Hydrosphere		Chlorinated hydrocarbons	Flowing water (Fw) Quiet water (Qw)	Due to Food Chain Dynamics { weeks to years months to years
		Heavy metals	Fw Qw	weeks years
		Oil	Fw Qw	Due to Food Chain Dynamics { weeks to years months to years

Exhibit 8-9

U. S. ENERGY NEEDS, 1980 to 2000

Forecast Body	Y E A R S			
	1980	1985	1990	2000
Ford Foundation (1974)	90.9	98.4	106.8	129.1
U. S. Atomic Energy Comm. (1973)	89.9	101.9	114.3	142.8
Alan Manne (1975)	87.8	98.4	114.3	148.1
National Academy of Engg. (1974)	98.4	114.3	No Forecast	No Forecast
U. S. Dept. of Interior (1972)	101.6	122.7	143.9	203.1

(in joules x 10¹⁸)

gas resources are insufficient to meet our energy requirements for the next 50 years (Exhibit 8-10). Large reserves of lesser-quality coal and oil shale exist (Exhibit 8-10). These involve serious problems concerning the potential for pollution and the cost of pollution abatement (Exhibit 8-11). Nuclear fusion would be a suitable solution except for a serious thermal pollution problem and the fact that the development probability is questionable before Year 2000 [Rose - 76].

8.2.4.1 COMPARING TERRESTRIAL AND ORBITING POWER PRODUCTION

Up to now and possibly for the next 20 to 25 years, all the energy produced for human use on Earth will come from the Earth's surface. After this period, the situation may change.

It is true that large or multiple power plants on the Earth's surface enable utilities to be more effective dealing with the complex financial, technical and environmental tradeoffs associated with modern power plants, but several serious problems develop: water requirements for cooling and heat loss, the loss of land use for other purposes, site location and acquisition, high-voltage transmission right-of-way, the environmental impact during large-site construction, highway and railway transportation, housing and services for the influx of employees and biological impact. These are only local or, at most, regional environmental problems. What about the global problems -- physical and social?

Two natural cycles will be affected by the increased energy production on the Earth's surface, the hydrologic and heat balance cycles. The amount of water needed by electric power generation increases enormously; e.g., consumed water would increase 3000-fold if generating capacity increases about 5-fold between 1980 and 2000. This is twice the flow of the entire Colorado River Basin [Olds - 73].

Large Earth-based power plants of the magnitude needed in the near future, 10 to 50 GW_e , will discharge large amounts of waste heat which will cause significant weather modifications such as additional cloudiness and precipitation [Brumraikan - 76].

"The ecology of the Earth simply may not be capable of sustaining or even tolerating the growth of power generating capacity as long as power plants are based on the principles of thermodynamics and have to use the surface of the Earth or its atmosphere as a heat sink or as a depository of its waste materials" [Glaser - 71].

There are numerous worldwide social problems associated with energy development: international resource trade relations, the growing super-industrial society with its increasing urbanization and the effect of these factors on the economic growth and development of all nations, whether industrialized or not.

Exhibit 8-10
SOME U. S. ENERGY RESOURCES

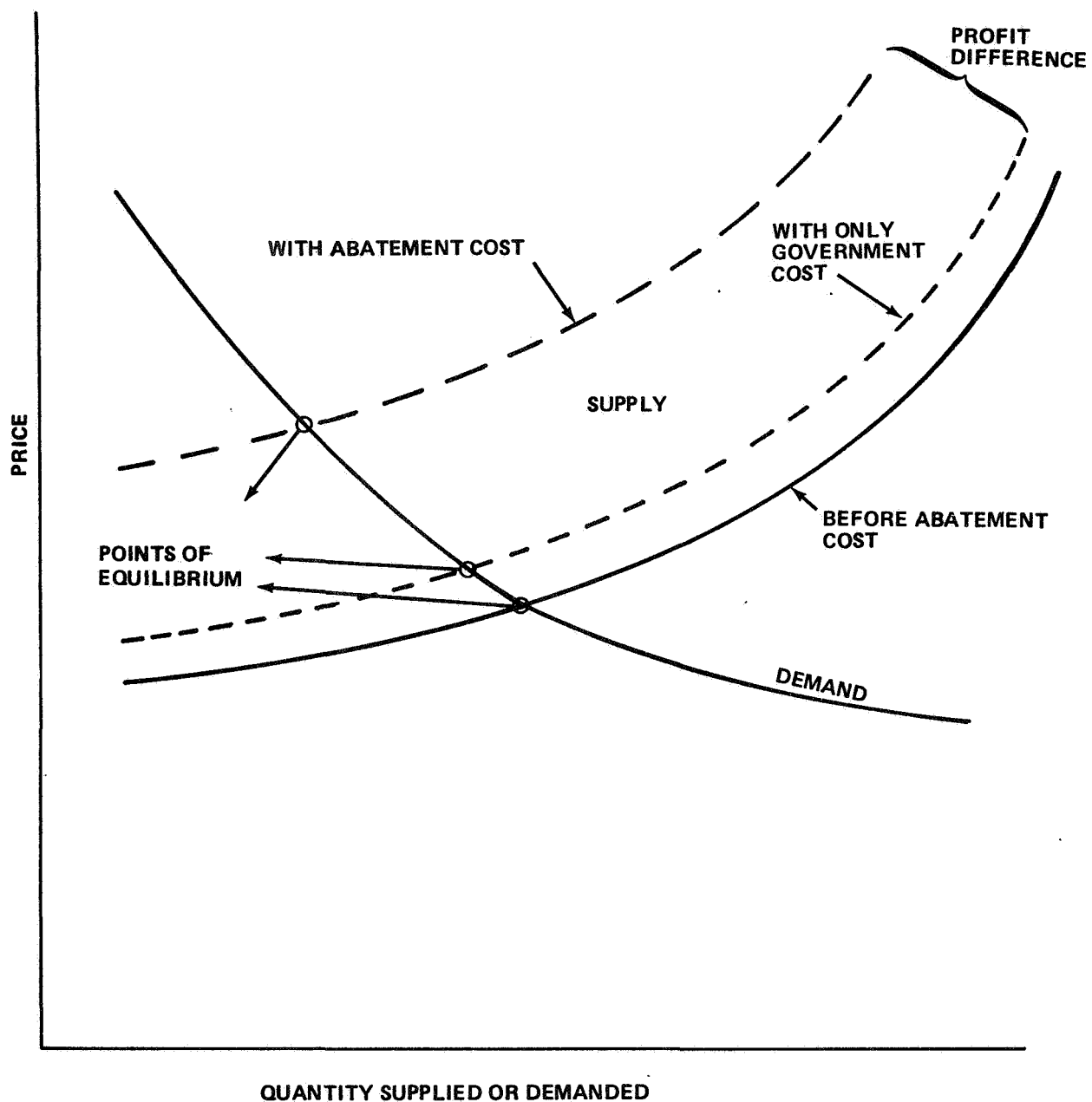
<u>Energy Source</u>	<u>Estimated Total Recoverable Reserves</u>	<u>Proved and Currently Recoverable Reserves^a</u>
Oil Shale ^b	1026 x 10 ⁹ barrels syncrude	74 x 10 ⁹ barrels syncrude = 430 x 10 ¹⁵ BTU
Coal	1443 x 10 ⁹ short tons	149 x 10 ⁹ short tons = 2980 x 10 ¹⁵ BTU
Crude Oil	386 x 10 ⁹ barrels crude	36 x 10 ⁹ barrels crude = 210 x 10 ¹⁵ BTU
Dry Natural Gas	1.412 x 10 ¹⁵ cubic feet	2.66 x 10 ¹⁴ cubic feet = 270 x 10 ¹⁵ BTU

^aEstimates based on current technology

^bColorado/Utah/Wyoming area only

Exhibit 8-11

EFFECT OF ELIMINATING POLLUTION ABATEMENT COST TO UTILITIES



One major contributor to the development of the U. S., socially and economically, has been the domestic availability of adequate supplies of low-cost energy resources. Energy is needed to obtain the quality of life this country enjoys. More energy will also be required if the underdeveloped countries hope to improve the living conditions of their people.

Space generation of energy has the potential of solving some of these physical and social problems. Specifically, the following advantages may be realized:

- ° Less pollution and damage to human health [Biersteker - 76],
- ° Less thermal pollution at the surface of the Earth,
- ° Reduced need for non-reuseable resources,
- ° Elimination of transportation problems,
- ° Reduction of coal production problems,
- ° Reduced cost of pollution abatement,
- ° Elimination of the problem of whether the technology is available for abatement of certain pollutants [Templeton - 74] and
- ° Decentralization of energy centers.

It is evident that the use of orbiting power stations should be looked at with considerable enthusiasm in the future. The positive environmental, social and political ramifications of such planning outweigh the possible negative impact of the financial problems.

8.2.4.2 COMPARING NUCLEAR AND SOLAR ENERGY POWER PRODUCTION

Both nuclear and solar energy are among the most R&D intensive technological areas in the world today. Developing these energy sources will center around engineering and manufacturing improvements and not around fundamental research.

1. Nuclear

As can be ascertained from Exhibit 8-12, there are environmental problems associated with using nuclear energy as an energy source. The possible hazards of nuclear power production can be divided into two categories: those associated with the actual operation of the fuel cycle for power production and those associated with the long-term storage of radioactive waste (Exhibit 8-13). The latter is the most serious. There are many ways of managing radioactive

Exhibit 8-12

ENVIRONMENTAL PROBLEMS COMPARED TO ENERGY TYPE AND LOCATION

	Surface		Orbital	
	Solar	Nuclear	Solar	Nuclear
CO ₂	(-)	(-)	(-)	(-)
Particulates	(-)	(-)	(-)	(-)
Albedo	(+)	0	(-)	(-)
Flooding	0	(+)	(-)	(-)
Heating	(+)	(+)	> 0	> 0
Radioactivity	(-)	(+)	(-)	> 0

(-) = decrease the problem

(+) = increase the problem

0 = no difference

Exhibit 8-13

ADVANTAGES AND DISADVANTAGES
OF
TERRESTRIAL NUCLEAR POWER PRODUCTION

Advantages

- Compactness of nuclear fuel makes it portable and reduces transport costs of fuel
- Relatively low cost: \$180 to 250/Kw for 500 MW or \$140/210 kW for 1000 MW in 1985 [Spinrad-71]
- No particulate or chemical pollution of the atmosphere

Disadvantages

- Licensing process
- Catastrophe insurance problems
- Credibility and related public opposition
- Thermal pollution: 40% more waste heat than a similar energy producing coal plant [Nakatani - 71]
- Land requirements for mining, milling and tailings
- Uranium mining runoff
- Great need for water
- Environmental radiation leaks and the associated unknown low limit of radiation danger
- The possibility of nuclear accidents
- Proliferation of nuclear weapons
- Waste disposal or storage of radioactive by-products

waste on or off the Earth [Smith - 76-2], but none solve the problem of safe radioactive waste storage.

Processing or elimination of nuclear fuels are not available alternatives presently; therefore, a costly storage mechanism is necessary [Cherico - 76; Kohn - 77-2]. The actual cost and the ultimate obligation for the storage of the radioactive wastes have not "been evaluated with sufficient clarity to justify the future burden to society of a program of relatively unrestricted power growth based on partially subsidized low-cost energy concepts" [Kubo - 73].

If nuclear energy generation is to be developed, there are definite advantages to orbiting nuclear energy power plants. They offer unlimited nuclear power without many of the nuclear hazards [Schneider - 76-2] or pollution, but at somewhat higher cost. "This is the price of virtually eliminating the problems of reactor safety, the plutonium underground market and the disposal of radioactive wastes on the Earth" [Williams - 75].

2. Solar Energy

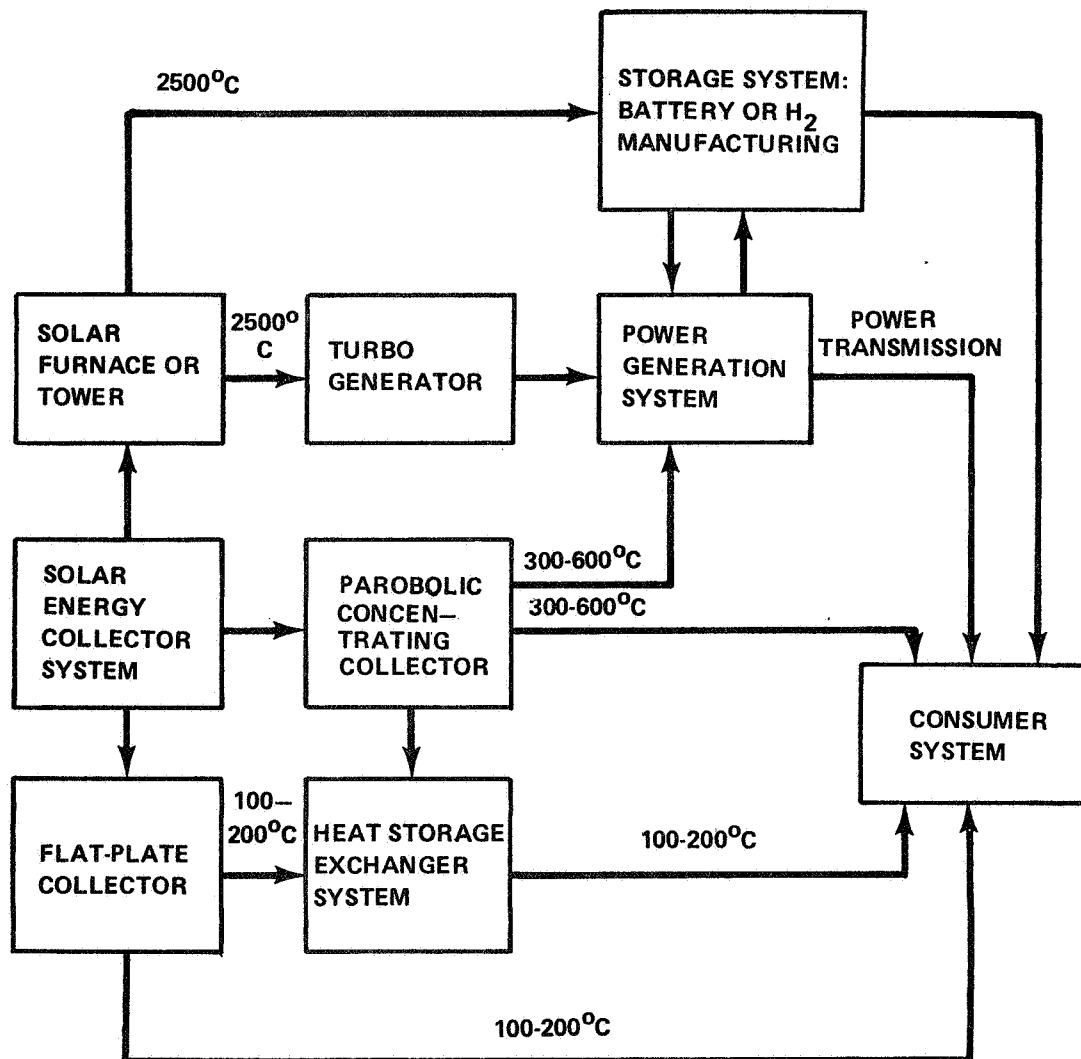
Solar energy arrives on the surface of mainland U. S. at the average rate of 4,000k cal/m²/day which equals 2×10^{20} k cal/m²/year [Cambel - 76]. Although the specific amount varies with latitude and weather conditions, all areas receive appreciable energy. The effective sunshine levels generally average only 6 to 10 hours/day, except for the arid areas of the Southwest and the Great Plains [Gervais - 75-2]. To effectively utilize this energy, storage devices must be available to compensate for periods of darkness and overcast skies. Solar radiation has a low energy density, approximately 1 kW/m²; therefore, large areas of land are required. It would require 3 percent of the U. S. mainland or about 241,900 km² to produce the equivalent of the total expected energy in the U. S. by the year 2000 with solar energy at an efficiency rate of 15 percent. The area of land is smaller than that of the state of Arizona. This use of large tracts of land is a minor environmental problem.

As was mentioned before, one of the most serious environmental problems is the possibility of increasing thermal load causing global climatic changes. If the thermal load increases by 0.5 percent, an appreciable imbalance will occur. At the present 4.4 percent increase of energy consumption, this imbalance will be reached within 100 years [Cambel - 76]. The use of terrestrial solar power stations will decrease this annual percentage energy increase so that atmospheric thermal imbalances can be delayed or mitigated. Another advantage of the terrestrial solar power station is the fact that multiple paths can bring energy to the consumer (Exhibit 8-14).

Internationally, the use of terrestrial solar energy for power

Exhibit 8-14

TERRESTRIAL SOLAR ENERGY POWER SYSTEM



production on the Earth will contribute to the developing countries in tropical arid and semi-arid regions. This is due to the fact that:

- ° "Established electricity and fuel supply systems are not existent or are small installations with high unit costs; thus, the solar energy system has a chance to compete.
- ° Solar insulation is reliable and high energy storage costs are not required.
- ° Energy requirements per square foot of land surface are as low as the production potential of the land is low. The low energy demand is compatible with the low intensity of insolation.
- ° The energy is used at the point of generation, thus eliminating the high transport charges to the isolated areas."

[Cambe1 - 76]

Solar electric power can raise the standard of living of these countries and reduce their dependence on industrial nations. This is the opposite of what would happen if nuclear sources are used. If nuclear power generation is developed, such a complex technology may only be purchased from 5, 6, or at the most, 7 countries. Thus, the less technologically developed countries will be dependent on the corporations who vend the equipment and service it. This would cause the living standards between the vendors and buyers to remain separated [Sheridan - 72].

The orbiting solar power satellite has all the advantages of a terrestrial solar energy power station and only a few disadvantages. Solar power satellites would intercept and convert solar radiation into electrical power available to the terrestrial power grids near the end users. Once constructed and operating the solar power satellite can provide economically viable and environmentally and socially acceptable power which can be built on present scientific realities and existing industrial capacity for mass production. However, there are technical problems which must be solved: the development of a light-weight, long-life, low-cost solar array; transportation; construction; operation and maintenance; and development and deployment of extremely large, light-weight structures. None of these problems should be difficult to solve.

The few disadvantages of the terrestrial solar plants are eliminated by putting the plant in orbit. In addition, the solar power satellite is more efficient than the surface plant (Exhibit 8-15). Exhibit 8-16 shows the flow of the energy from orbit to the user of the electricity on the ground.

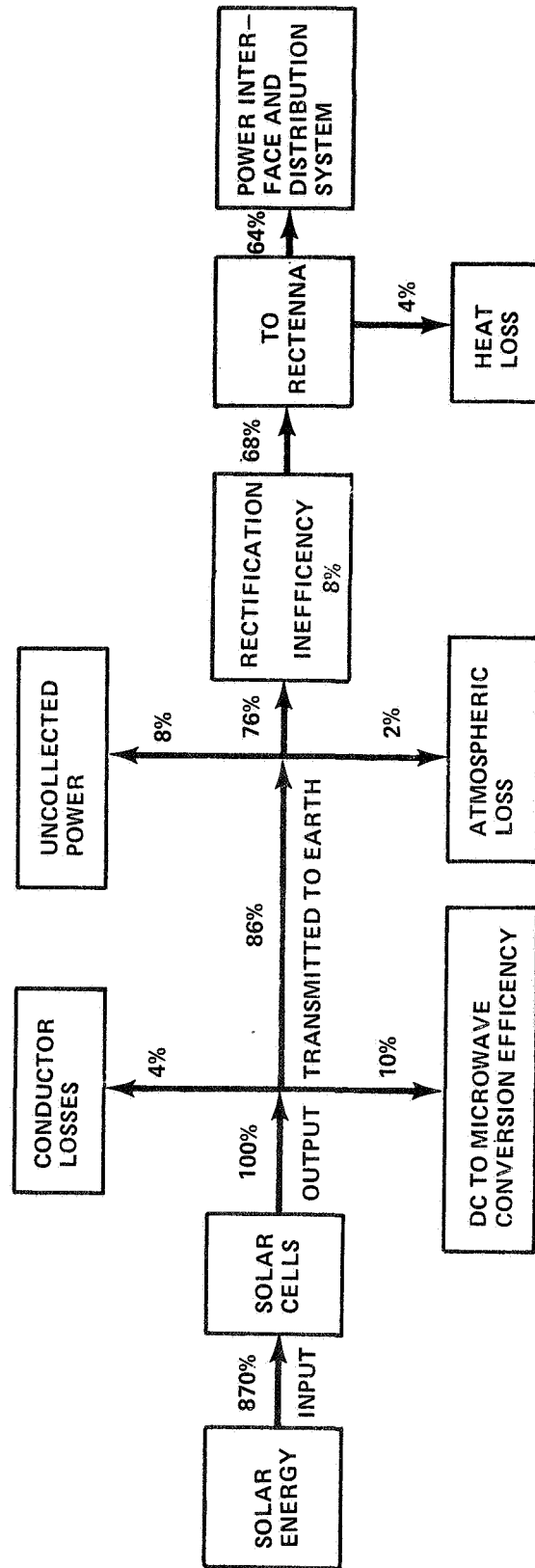
Exhibit 8-15

A COMPARISON OF SOME OF THE PHYSICAL CHARACTERISTICS OF THE
 TERRESTRIAL SOLAR POWER STATION (TSPS)
 AND THE SOLAR POWER SATELLITE (SPS)
 [Morrow - 73; Brown - 73]

	TSPS	SPS
Needed Area (Earth)	100Km ²	10Km ²
Collector Area	50Km ²	32Km ²
Photovoltaic cell efficiency	12%	20%
Electrolyzer efficiency	95%	Efficiency of microwave system 70%
Net efficiency to produce H ₂	11%	14%
Fuel cell efficiency	80%	85%
Net efficiency	9%	12%

Exhibit 8-16

FLOW OF POWER IN THE SPS ENERGY SYSTEM



The amount of energy received at the satellite's collectors is taken as 100 percent. The actual amount available is greater; i.e., 870 percent. This indicates one major advantage of the solar power satellite over the earth-based solar power station -- greater energy availability. "The system receives full sunlight, unattenuated by atmospheric absorption for all but a 1.2-hour interval every 24 hours for 25 days before and after equinox in the 35,600 km geosynchronous orbit proposed"[Berman - 72]. This can be overcome by using multiple space stations, thus eliminating the need for a storage system. The greater availability of energy also means the solar power satellite can generate more power or save resources by not having to have such large photovoltaic collector arrays. There is also the advantage that the solar power satellite will not be affected by such deteriorating conditions as wind, precipitation, sand, dust and rocks thrown by children, although some deterioration by ion particles and meteorites will occur.

The principal negative effects of the solar power satellite on the environment will occur during the construction period (Exhibit 8-4). If the solar power satellite system is developed, there will be a drastic increase in rocket flights through the atmosphere thus increasing particulate loading with subsequent effects on the climate and atmospheric chemistry; especially stratosphere and ionosphere (Exhibit 8-17). The particle concentration will vary, depending on the type of fuel and engine of the spacecraft, and on the residence time of the particles in the atmosphere.

The social costs of the environmental impacts due to the loss of land for launch sites, mine and milling of the necessary resources, and the aesthetic effects of such land use need to be established so that the benefits of the solar power satellite can be weighed against the potential dangers and the effects on the quality of life, which is what an EIS is supposed to do. Exhibit 8-18 shows the possible advantages and disadvantages of the solar power satellite system.

8.2.5 MATERIAL PROCESSING IN SPACE

The effect of material processing on the environment will be minimal except in 3 areas: noise, pollution of the troposphere and the legal ramifications (Exhibit 8-3).

Noise will be a serious problem where the materials are mined and milled and at the launch facilities. Although these are local environmental problems, they must be solved.

The pollution of the troposphere is due to the materials mining and milling operations and the exhaust of the space vehicles taking the material to orbit.

The legal problems (see Section 8.4) will be due to the difficulty in developing a workable plan for the use of space by all countries.

Exhibit 8-17

POSSIBLE EFFECTS OF MICROWAVE PROPAGATION AND EXHAUST PRODUCTS OF SPACE VEHICLES

A. MICROWAVE PROPAGATION

Ionosphere

1. Electron-temperature increase
2. Electron-density decrease in D-region, increase in F-region
3. Modification of electron energy distribution
4. Anomalous absorption and heating, leading to field-aligned irregularities and radio-scattering phenomena

Thermosphere

5. Neutral temperature increase
6. Modification of relative composition
8. Excitation of atmospheric gravity waves

Mutual Coupling Effects

9. Neutral composition affects the electron-ion recombination rate
10. Ion density affects the neutral-wind system
11. Neutral winds and gravity-wave structure affect the ion distribution

B. EXHAUST PRODUCTS OF SPACE VEHICLES

Ionosphere

1. Substantial depletion ($\geq 50\%$) of the total height-integrated electron density creating a "hole" in the ionosphere creating problems for communications systems
2. Molecular effluents could affect the ionosphere's D-layer density therefore significant alteration of the D-region

Stratosphere

3. Cloud formation in the stratosphere
4. Increased electromagnetic scattering
5. Possible reduction of the ozone layer by the exhaust of NO_x and chlorine compounds

Surface

6. Climatic change

[Falcone-70; Michae]son-2-71; Milroy-2-71; Mumford-61; Ching-77]

Exhibit 8-18

THE ADVANTAGES AND DISADVANTAGES
OF THE
SOLAR POWER SATELLITE SYSTEM
[Glaser - 75, 77; Brown - 73]

Advantages

1. The energy density of the solar radiation at GEO is 6 to 11 times that at the earth's surface.
2. After construction, absence of particulate, chemical, or radioactive pollution.
3. Power can be delivered to most geographically desirable areas.
4. Low thermal pollution due to the very high efficiency of the rectenna; much of it would be radiated back to space.
5. A dependable, inexhaustible source of energy.
6. Rectenna is compatible with other land uses and can be built on water.
7. A favorable operational deployment of large-area, low-weight structures leads to a marked reduction in materials used per unit of delivered power.
8. The space vacuum permits the operation of microwave generators and other components without the evacuated enclosures required on earth.
9. The energy required to produce the materials required during the construction, and the propellants to place the materials into orbit, would be amortized in one to two years of solar power satellite operation.
10. Eliminate the need for energy storage.

Disadvantages

1. Fluctuating power output: 1.309 kW/m^2 on July 4th to 1.399 kW/m^2 on January 3rd.
2. Needs large areas of land for rectenna; 2000 km^2 if 50, 10 GW stations are built; i.e., 40 km^2 each.

Exhibit 8-18 (Continued)

3. Possible biological and weather modification effects due to micro-wave transmission from orbit to earth (Exhibit 8-17).
4. Possible radio frequency interference to amateur sharing, state police radar, and high-power defense radar if the 3.36 Hz frequency is used.
5. Limited space in GEO, and legal rights to the use of space.
6. Potential for military action against the station.
7. Political problems -- U.S. Government has announced intentions to be against nuclear energy use, then takes advantage of others by being the only country able to beam energy from orbit; a monopoly.

8.2.6 SERVICES

Services are principally concerned with communications and observations.

Communications has little effect on the environment except for some noise due to space vehicle launch (Exhibit 8-4). However, this is over-balanced by its great help to education and its benefit to criminology.

There are no serious environmental problems associated with observation service and only the political scene will be affected (Exhibit 8-4) due to a country being able to look down upon another with immunity. Most important for observation is its positive effect on many of the environmental problems of the Earth. It will help observe the problems of pollution -- air, water, soil and waste -- and assist in land use and mainly in the determination of climatic change. "A satellite observation program, closely integrated with ground-based and atmospheric measurements and with a detailed program of theoretical analysis, will be needed for more precise predictions of climate changes and for developing the means to effect desirable global controls" [Penner - 76].

The reason for the other positive effects of observational service is the use of remote sensing in monitoring ecosystem dynamics and the development of strategies and methodologies for the most effective management of natural resources and in the development and implementation of measures to protect the environment [Thie - 74]. The use of satellite remote sensing has made possible the study of the following topics: (1) monitoring of natural environmental change [Brown - 73; Lovill - 72; Prabhakara - 70-2, 73-3, 2; Heath - 73-2], (2) environmental impact assessment and prediction, (3) environmental protection surveillance [Ludwig - 73] and (4) long-term environmental monitoring [Kellogg - 72].

8.2.7 CONCLUSIONS AND RECOMMENDATIONS

New techniques will be used in the development of space industrialization and may bring serious potential environmental hazards that require positive actions to avert or minimize. In fact, there are many beneficial uses of space industrialization that could very well over-balance the potential negative effects. It must be remembered that there is a growing awareness and concern about the way in which technology is applied. Society will demand, in connection with the introduction of new technology, a more cautious and careful approach than the scientific and industrial segments have been using. The decision makers and the public must be better informed of the program and any environmental impacts which may occur.

The EIM may be the start of an outstanding environmental assessment of space industrialization. The EIM forces an observation of

the interrelationships of the individual components of the natural and induced environments. It approaches the quantitative assessment of the environment by assigning value ratings to each naturally-induced environmental interaction and finally it may identify the critical and controversial areas.

NASA has the opportunity to do what many governmental agencies and industries have not done -- address the environmental problems before being forced to by the law and a concerned public.

RECOMMENDATION: NASA should perceive, understand, define and act upon the effect of space industrialization on the environment. This implies: (1) the preparation of an EIS for various phases of space industrialization, (2) making every effort to understand the mechanisms which govern climate and climatic change and (3) starting a satellite program to examine the "normal conditions" of the atmosphere before increasing the launch rate of space vehicles.

The development of a long-range national goal such as the use of non-terrestrial materials or the development of a hydrogen economy may be desirable. This may help assure Americans that they will have an adequate supply of energy and a satisfactory living environment in the future.

By developing the use of non-terrestrial materials, NASA would give the human race the capability to expand a finite amount of resources to an ever expanding "unlimited" supply. It would also negate the abuse of Earth resources and the increasing associated environmental problems (Exhibit 8-4, Earth Resources vs. Extra-Terrestrial) and allow a cost reduction for the solar power satellite system. The money and energy saved and developed by the solar power satellite system might be used for the development of the hydrogen economy [Billings - 75; Eisenstadt - 75-2]. Jules Verne wrote of the possibility of hydrogen economy in the book, "Mysterious Island," one century ago -- "Yes, my friends, I believe that water will one day be employed as fuel, that hydrogen and ozone that constitute it, singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable. Water, decomposed, doubtless by electricity, which by then will be a powerful and manageable force, will be the coal of the future" [Verne - 1870]. As Verne predicted, men have gone to the Moon; it is also time society caught up to Verne in the energy field.

8.2.8 SUMMARY

The current energy, resource and environment situation is characterized by confusion, misunderstanding, fragmentation and misdirected incentives. NASA has the capability to assist with the solution to

many of today's environmental problems. Possible solutions that could be developed by NASA are:

- ° The development of an orbiting solar power satellite system
- ° The development of a hydrogen economy
- ° The development of non-terrestrial materials

Materials processing in space will not achieve its potential without the use of non-terrestrial materials. True, these long-term goals seem impossible to many, but they must be approached and started now so that the future will become bright for the human race. For this to happen, NASA must become a lobby for the future.

8.3 HUMAN RESOURCES ACCOUNTING

The accounting system is a formal device to measure team financial performance, but accounting conventions lead to write-offs as expenses, outlays that should be carried forward as assets. The system also adheres to historical costs and ignores changes in the real value of some assets. The accounting system is a means to set long-range goals and to influence management behavior [Horngren - 72].

Should human resources be treated as capital assets or as expenses?

Conventional accounting systems encourage the misuse of human resources, with pressure for short-term profits leading to unnecessary and uneconomical action. They ignore the need for more employee participation in decision making. They do not measure the human organization and its relationships to events at the outcome. The attempt to gather this information is known as human resources accounting.

Incorporating human resources accounting into the formal accounting system would entail, at least, regarding the outlays or costs for recruiting and training personnel, as assets. These costs would be amortized over the expected useful lives of the employees.

Three routes or methods of human resources accounting exist:

1. Incurred costs [Pyle - 70]
2. Replacement cost [Franholtz - 69]
3. Present value [Likert and Bowers - 73]

The latter was selected recently [Pecorella - 76] to develop and refine methodology for organization assessment of the Navy and Marine Corps.

Current financial reports may include dollar estimates of the change in value of human organization. A kind of management will be fostered that creates the will to work and contributes to employees health and satisfaction. This management system is claimed to build 20 to 40 percent more productive organizations than usual systems [Likert - 73].

Human organization efficiency can be measured by a few key dimensions, which fall into two classes: causal and intervening (or intermediate). Causal variables categories are: (1) organizational climate and (2) managerial leadership. Thus, management can alter causal variables, thereby changing intervening variables and the end result performance variables.

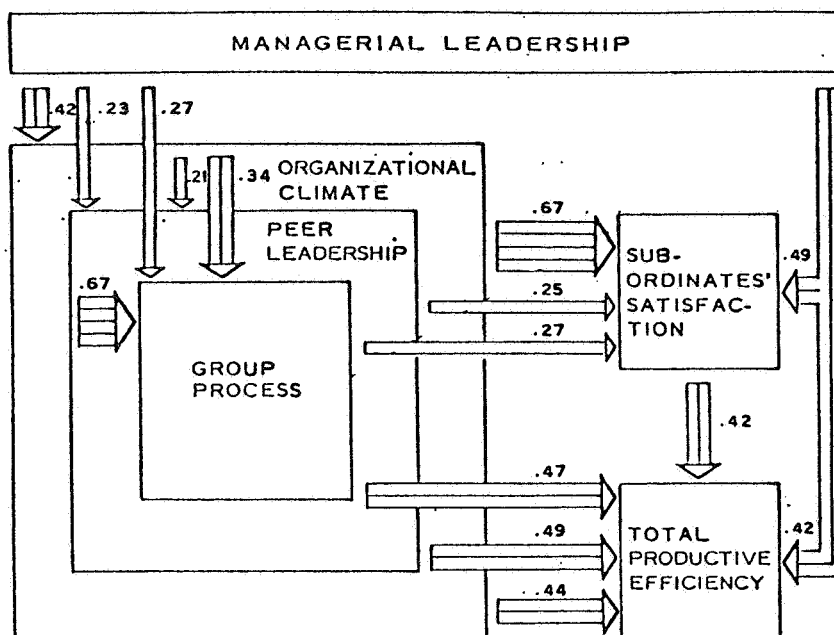
Elements used to measure the interdependent causal and intervening variables with respect to a human organization are:

Causal	Intervening (intermediate)
Managerial leadership	Peer leadership
Goal emphasis	Goal emphasis
Help with work	Help with work
Team building	Team building
Support	Support
Organizational climate	Group process dynamics
Personnel influence on management	Planning together, coordinating efforts
Decision making practice	Making good decisions, solving problems
Communication flow	Sharing information
Motivation feeling	Wanting to meet objectives
Concern for people	Having confidence, trust in others
Technological adequacy	Know-how, ability to meet unusual demands
	Satisfaction (with)
	Fellow workers, supervisors
	Job, pay, chance to progress

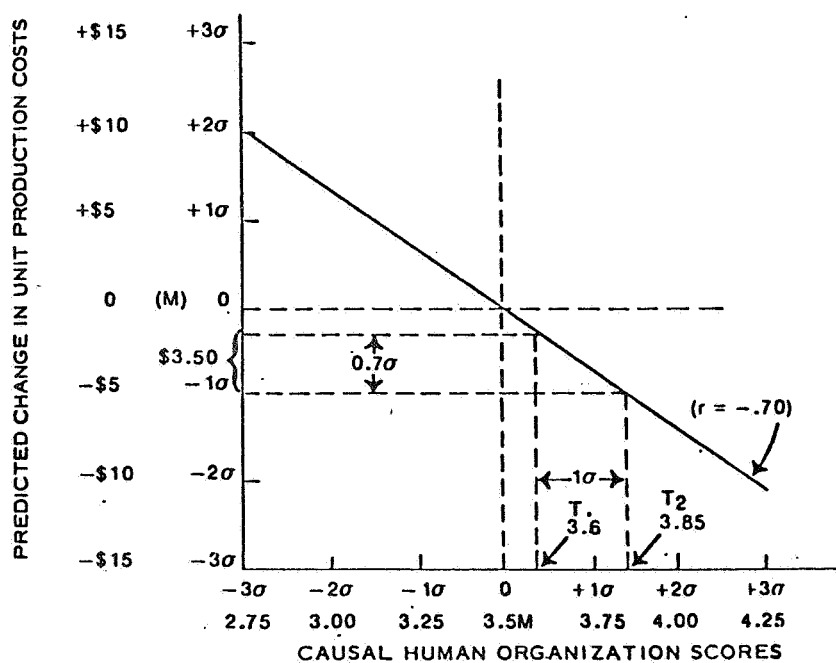
The end-result dependent variables reflect the achievements of the human organization: productivity, costs, scrap loss, earnings and market performance.

Exhibit 8-19 shows the magnitude of the relationships among the human organization variables and those to performance/production variables. The width of each arrow is roughly proportional to the magnitude shown.

Exhibit 8-19
Relationships Among Human Organizational Dimensions
and to Performance



Translating Human Organizational Values
into Dollars



[Likert - 73]

Exhibit 8-19 also shows an example of the translation of human organizational causal variables into production costs in dollars. This estimate in dollars of the change in productivity is used to compute change in value of the human organization as a capital asset [Likert - 73].

A management system, called System 4 [Likert - 73], is based on the principles and insights of achieving the highest productivity and lowest cost. That achieves a highly productive human organization with the most satisfied and healthy employees and best labor/management relations. To explain, System 1 is exploitative-authoritative; System 2 is benevolent-authoritative; System 3 is merely consultative and System 4 is participative-cooperative.

In System 4 climate, these factors are present:

- ° A great deal of confidence and trust is shown in subordinates.
- ° A great deal of cooperative effort and teamwork exists.
- ° Information flows in all directions (downward, upward and sideways).
- ° Subordinate ideas are sought and used constructively.
- ° Subordinates are fully involved in decision-making processes.
- ° Organizational goals are established by group-dynamics action.
- ° Review and control functions are widely shared by all.

The working environment, where human resources are treated as assets, rather than expenses, will contribute to attraction and retention of high-quality personnel, who shall be eager to do their share for materials processing in space.

Treating personnel as expenses may help to get short-term profits and cost reductions, but System 4 achieves the organization's long-range goals by dealing with people as capital assets. It also achieves high-productivity, low-cost tasks while keeping good labor/management relations.

RECOMMENDATION: NASA should implement human resources accounting for future space programs.

8.4 ADEQUATE LEGAL STRUCTURE

8.4.1 SPACE LAW: 1958 - 1977

International law in the past has grown as much by custom as by formal treaty. In the new field of Space Law, where there were no exact precedents, it was quickly recognized that general principles must be established. Early formulation of principles was stimulated by the concern over military missile programs, particularly following the launch of Sputnik 1 and from the desire to regulate, from the beginning, potentially dangerous (e.g., nuclear) activities in space [Horsford - 76].

The normal, slow, evolutionary growth of legal structure might have predicted a path following bi-lateral agreements between the U.S.S.R. and the U. S. progressing into multi-lateral agreements with ESA's entry into the space effort. Following this, as more and more countries become involved, the development of U. N. treaties would be expected. General development of space industrialization might lead to multi-national corporation efforts, showing the need for specific controls and precautions. However, due to the unusual international nature of space, various treaties and agreements were quickly formulated.

Since 1958 there have been hundreds of bi-lateral and multi-lateral space agreements concluded among nations engaged in space programs. Concurrently, U. N. international space agreements, formulated within the U. N. Committee on the Peaceful Uses of Outer Space, were drafted by consensus method. "The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies" was signed on 27 January 1967 by the United Kingdom, the United States and the Soviet Union. By 1976, 70 other governments had signed. China had not. For a list of treaties and text of the 1967 Space Treaty see Appendix I and J.

The 1967 Space Law Treaty, Article I, provides that space exploration shall benefit all countries. National appropriation is prohibited, similar to the high seas. Resources or the location of resources cannot be appropriated for nation-state use, only for community use; i.e., U. N. However, it is questioned whether the comparison to the high seas is meaningful and whether peaceful shared usage is possible. It is possible that an effort to remain within the provisions of the treaty would be instrumental in increasing cooperation between the nations.

The Space Law Treaty also prohibits the establishment of military bases of various kinds, weapons testing and military maneuvers on celestial bodies and provides for the inspection on a reciprocal basis of space stations, installations, equipment and space vehicles on celestial bodies.

The Nuclear Test Ban Treaty extends to outer space. It provides for the prohibition of nuclear explosions in outer space and in the atmosphere of celestial bodies. The legality of putting any nuclear material into space from Earth must be examined before such projects as nuclear waste disposal on the Moon can be pursued. DoE and NASA are most likely to have interest in the peaceful use of nuclear power and/or wastes in space. They should both begin to consider how their projects fit into the legal requirements.

It is possible that celestial bodies could become like a U. N. owned island territory, which could be leased by various nation-states for long periods of time for resource extraction, while space itself would be legally treated like the high seas. International Space Law may provide constraints on both organizational structure and program costs in such a magnitude as to be of overriding importance to the system.

The Rescue Agreement of 1968 on the rescue and return of astronauts in distress implements the rules of the Convention of 1967 by enlarging the scope of the earlier Convention.

In 1971, the Treaty on Liability for Damage Caused by Space Objects was signed. It provides for a 3-man International Claims Commission to be set up in cases where a settlement satisfactory to both parties cannot be reached through diplomatic channels. In January 1975 this Treaty was supplemented by a Convention on Registration of objects launched into outer space. This Treaty requires proper identification and a central registry of all space objects.

A draft Treaty on the Moon is under consideration by the Legal Subcommittee of the U. N. Committee on Outer Space to establish use of the Moon exclusively for peaceful purposes in the interests of all nation-states. One of the most complicated problems of this treaty is the question of the use of Moon resources [Gorove - 76].

There is concern at present over the legal problems of the use of the geostationary orbit. There are plenty of geostationary parking places. It is not the actual number of satellites per unit area which is of concern, but rather the number of satellites per unit area broadcasting on the same frequency causing disturbance of other transmissions. The number of satellites and communication channels that can be accommodated at any particular time is a function of the state of technology and how it is used. The International Telecommunication Union Radio Regulations and future technological improvements should be able to handle future situations [Gehrig - 76].

8.4.2 LEGAL PROBLEMS OF SPACE VENTURES

All successful ventures in space have been begun by government space programs; e.g., COMSAT, LANDSAT and weather satellites. According to the National Aeronautics and Space Act of 1958, "The Congress

declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities." The Act says that except for DoD work, this is the responsibility of NASA. NASA is to work towards the "preservation of the U. S. as a leader in aeronautical and space science and technology and in the application thereof...". If it can be shown that other countries are pursuing materials processing and space industrialization efforts, then it becomes obvious that it is something the U. S. cannot ignore. Such justifications as national prestige, balance of payments and technological leadership apply. (Initial Congressional justification of the U. S. Supersonic Transport (SST) Program was: (1) national prestige, (2) leadership in aviation, (3) benefits to U. S. industry, (4) technological advances and (5) balance of payments [U. S. Congress - 60].) It is, of course, rather difficult to identify exactly at what level the expansion of space activities should take place. This is examined further in Chapter 5 and Section 7.2. Some groups, not wanting to wait for government to proceed into space for purposes of habitation and industrialization, have tried to proceed without government aid.

There were two private corporations established in the U. S. to achieve the objective of human habitation in outer space: The Committee for the Future (1970) and the New Worlds Company (1971). The latter was to develop an entrepreneurial venture beginning with the Moon. However, two things became evident in the New Worlds Company. First, "NASA, DoD, certain international federations and members of the U. S. Congress representing various space sciences committees" would not welcome this effort and, secondly, there was no recognizable return for a commercial business venture [Robinson - 73].

Investigations into the legal and political policies of entrepreneurial space activities indicate that adjustments must be made in the present policies if these activities are to succeed. Battelle recently completed a study on the ways that NASA could move to protect the proprietary rights of commercial users [Day - 77]. The study emphasizes the need for industrial/user security and offers 11 guidelines concerned with providing more security for the user and promoting an awareness within NASA of the needs of the entrepreneur.

8.4.3 SUMMARY AND RECOMMENDATIONS

Internationally, the success of space law has shown that nation-states recognize the need for international cooperation prior to conflict. There is a desire to prevent the militarization of outer space before it begins, instead of trying to obtain limitations and cutbacks [Demilitarization - 76]. Future space law will continue along this line, trying to predict and prevent problems, trying to protect the rights of developing countries, using space as a testing ground, providing insight and experience in international cooperation for both terrestrial and space situations.

The specific problems which need attention in relation to space industrialization are:

1. International space resource allocation issues. The uncertainties of space resource allocation will prevent entrepreneurial plans for its use until those uncertainties are resolved.
2. Non-militarization policies. Any designs or plans for space industrialization must include concern for non-militarization of space. It cannot be assumed that because something is "called" non-military, all nation-states will believe that it is not a cover for military operations. Provisions may have to be made to allow for such things as international space station inspection while still maintaining industrial security.
3. The need for greater security for the entrepreneur. Providing adequate industrial security for the entrepreneur has not yet been adequately pursued. NASA will need to adjust to the needs of the entrepreneur if there is going to be adequate incentive for a private business venture.

It is necessary to investigate how space industrialization is constrained by these problems and at what level these issues become so overwhelming as to destroy the viability of an entrepreneurial venture.

8.5 QUALITY OF LIFE

Quality-of-life considerations must be included in this model because of the increasing concern Americans have for the scale and scope of current technology. Americans have been critical of the space program because they have the impression that huge amounts of money are involved. In reality, the Department of Health, Education and Welfare spends NASA's budget every nine days. People often ask the questions -- "If we can go to the Moon, why can't we deal with the urban blight problems?" or "If we can go to the Moon, why can't we feed the people on Earth?" These are relevant questions and do need to be addressed, but the more important issue which these questions direct attention to is that of quality-of-life considerations with respect to a technology. The technology of doing materials processing in space is being considered. It must be asked, "How will this improve or affect the quality of life for the people of this nation (or perhaps this world)?" "What technology transfer will take place?" [Bortman - 76; Kubokawa -76].

For the Western world it has been suggested [Steg - 75] that freedom, justice, general welfare and security-survival are the main values in quality-of-life considerations. These might be considered as grand abstractions, however, and greater specificity must be inherent in the goals if change is to be measurable. An attempt to make these abstractions operational is shown in Exhibit

8-20. Exhibit 8-21 shows the criteria which might be used to judge system performance on both an organizational and national scale.

How can these indicators be measured on this project? What alternative mechanisms may be used to consider quality-of-life changes as affected by materials processing in space? Here are 5 alternatives to be evaluated:

1. A study by the Office of Technology Assessment (OTA) commissioned by Congress.
2. A general public survey by a contractor to NASA.
3. A Delphi-computer conference carried out by NASA.
4. A social impact assessment by a team of sociologists under contract to NASA.
5. The funding of a number of small projects (assigned to soft-science teams at universities) by the NASA planning office.

The criteria used to assess these alternatives are somewhat subjective as is this whole area of discussion. The criteria may be briefly stated as that of seeking the alternative which will give the most information for the least money without conflict of interest.

Consider the first alternative. OTA is basically set up to do just this kind of study [Wenk - 75; DeSimone - 75; Coates - 74]. The study should include some of the more recent work on social impact assessments [Finsterbusch - 77]. The main advantages are: (1) OTA has an established mechanism for performing the study, (2) conflict of interest is minimized and (3) OTA has a prior knowledge of NASA operations. Some disadvantages are: (1) potential instability of OTA, (2) cost, (3) technology assessments often do not identify the important issues and (4) OTA may not give this problem-priority.

The second alternative would be pursued by a public affairs consulting firm who would develop an instrument to measure public response to postulated situations related to materials processing in space. The advantage would be a broad-based input. The disadvantages would be: (1) difficulty in developing the instrument, (2) questionable level of response, (3) probably quite expensive and (4) conclusions may reflect conflict of interest (contractor paid to get reinforcing results).

The Delphi-computer conference, the third alternative, combines a Delphi questionnaire with computer conferencing. The Delphi technique is a method of arriving at a group consensus on the solution to a complex problem by means of iterative individual interrogations [Dalkey - 72; Coates - 76]. In relation to this project, the

Exhibit 8-20

National Performance Abstractions: Grand and Intermediate

	<u>Grand Abstractions</u>	<u>Intermediate Abstractions</u>
Satisfying interests	Peace, security, freedom, liberty, autonomy, self-determination, equality. Tolerance, dignity, honor, prestige, pride. Progress, culture, beauty, the arts, self-development.	Full employment. Fair employment. Equitable income distribution. Higher living standards.
Producing output	Abundance.	Growth in national output. Output of specific services or goods. Price stability.
Investing in system	Expansion, unity, national consciousness. Saving free enterprise, building socialism or a new or great society.	Investment in hard goods. Investment in people or institutions. Conservation and development.
Using inputs efficiently		Productivity ratios. Balanced budget.
Acquiring resources	Economic independence or self-sufficiency.	External assistance. Economic independence or self-sufficiency. Favorable balance of payments.
Observing codes	Justice, equity. Democracy. Order, duty. Obedience to God or gods.	Law enforcement. Due process. Fair procedures.
Behaving rationally	Reason. Wisdom.	Scientific or technological progress. Good government or administration.

[Gross - 66]

method provides means for:

- ° Examining the significance of historic events
- ° Putting together the structure of a model
- ° Developing casual relationships in complex social, economic and political phenomena
- ° Distinguishing and clarifying real and perceived human motivations

[Smith - 77]

Following the use of the Delphi questionnaire, computer conferencing would be used to gain collective agreement. The technique is discussed in Turoff and Linstone [Turoff - 75]. The Delphi-computer conference brings about the following:

- ° Offers an easier, more flexible way to assess and exchange human experience
- ° Increases the size of "common information space" shared by the participants
- ° Raises the probability of discovering and developing latent consensus
- ° Emphasizes interaction rather than hierarchy
- ° Indicates symbiotic adjustment rather than fragmented competition
- ° Seeks rational and contextual representations

[Smith - 77]

This effort could be coordinated by NASA or by an outside contractor. The advantages are: (1) the method is broad based, (2) conflict of interest could be minimized and (3) there is good assessment of subjective factors. The disadvantages are: (1) the possible high cost, (2) complexity and (3) the participants must at least be familiar with computer techniques.

The fourth alternative requires the preparation of what is now being called a social impact assessment [Finsterbusch - 77]. Methods used to prepare such assessments are now receiving considerable attention [Unsel - 77; Moore - 77; Auger - 76]. The methodology is discussed by Finsterbusch and Wolf [Finsterbusch - 77]. NASA would contract with a team of sociologists to prepare the assessments. It would address performance elements such as those in Exhibits 8 - 21. This could be used to

support the required environmental impact statement. The advantages are: (1) the method is broad based, (2) cost is reasonable and (3) it could develop a quantitative method of investigating social values. The disadvantages are: (1) possible conflict of interest, (2) complexity of data and (3) there may be difficulty in interesting qualified scientists.

The final alternative is an option for which the mechanism exists. NASA's Advanced Programs Office is now preparing to issue 2 million dollars in many small research grants to the academic community. Some of these studies could relate to quality-of-life considerations. Studies might be directed toward each of the 7 factors listed in Exhibit 8-21. A risk assessment [Otway - 76] might be done as one of the studies. The advantages are: (1) cost, (2) the mechanism is already established and (3) minimum conflict of interest. The disadvantage will not achieve an integrated overview of the quality-of-life problem.

Tradeoff variables are then analyzed for each of these alternatives. The results are shown in Exhibit 8-22.

RECOMMENDATION: The Design Team recommends the preparation of the social impact assessment. Alternative second choices could be the Delphi-computer conference or the OTA study. Since the small projects will likely be pursued anyway, they could provide input to the OTA study or the social impact assessment.

8.6 SPACE PROGRAM AWARENESS

Program awareness involves the operating mechanism by which the public understands the programs of NASA and their resulting benefits. Public understanding is a requirement to achieve an acceptable socio-political climate for materials processing in space.

Direct "advertising" of NASA or its programs is beyond the constraints Congress has placed upon this agency. Congress has, however, commissioned NASA, as a part of its mission, to inform the public. Examples of some currently effective methods of accomplishing this goal are:

- Operation of the Technology Utilization function of NASA
- Congressional hearings on budget appropriations
- News releases on planned programs
- Tours of NASA sites
- Research contracts with the academic community

Exhibit 8-22

QUALITY OF LIFE TRADE-OFF ANALYSIS MATRIX

TRADE-OFF VARIABLES	ALTERNATIVES				
	OTA STUDY	GENERAL SURVEY	DELPHI-COMPUTER CONFERENCE	SOCIAL IMPACT ASSESSMENT	SMALL PROJECTS
COST	-	-	0	-	+
KNOWLEDGE OF NASA OPERATIONS	+	-	-	-	-
POTENTIAL HIGHLIGHTING OF IMPORTANT ISSUES	0	-	+	+	-
EXISTING MEANS FOR STUDY	+	-	-	-	+
CONFLICT OF INTEREST	+	0	0	0	+
THOROUGHNESS	0	-	+	+	-
STABILITY OF STUDY CAPABILITY	-	0	+	+	0
SUBJECTIVE ASSESSMENT	+	-	+	+	0

LEGEND:

- + ADVANTAGE
- 0 QUESTIONABLE
- DISADVANTAGE

- Summer engineering design and research programs
- The use of college students on co-op programs
- The use of Requests for Proposals (RFP) for various programs
- The use of advisory committees
- "Getaway Specials" for Shuttle payloads -- Project Enterprise [Moore - 77] and Project Explorer [Dannenberg - 77].
- Announcement of Opportunities for planning or flight
- Traveling exhibits
- Films, TV releases, radio programs
- Speakers bureau
- NASA employee participation in professional societies
- NASA employees teaching at universities
- Advertisements mentioning NASA by private companies
- Spacemobile (teacher workshops)

Though these are effective methods, statements of people inside and outside NASA indicate that NASA's image needs polishing. This, in spite of NASA being the most efficiently managed government agency [Rosenberg - 77]; likely being the only government agency that has returned more to the national economy than it has absorbed and, finally, that NASA spinoff technology has touched nearly every phase of public life [Spinoff - 76; Spinoff - 77; Kubokawa - 76].

Money spent, directly or indirectly, on program awareness is less than 1 percent of NASA's budget. Since NASA's charter requires the dissemination of information to the public, it seems this amount should be increased. The Design Team has considered the following alternatives to achieve program awareness for materials processing in space (See also Exhibit 8-1):

- Establishment of a national space goal
- Preparation of a social impact assessment
- Formation of two additional advisory boards and identification of the materials processing program with a national goal

If a consensus national space goal could be found, public awareness would come about through the esprit de corps which typically develops incident to the pursuit of such a goal [Harkins - 77]. This was certainly the case with the Apollo program. That program, however, developed out of a unique political and economic situation. It would be difficult to say the least, to arrive at a consensus goal without an executive directive. Assuming a consensus space goal could be found, the materials processing program would likely be carried along with the other efforts to accomplish the goal. The following space goals were discussed by the Design Team:

1. Establish a solar power satellite system.
2. Establish a "hydrogen economy."
3. Establish a lunar colony.
4. Establish a closed ecological system in space (space colony).
5. Develop the use of extra-terrestrial resources.

The second alternative involves the social impact assessment which was discussed in Section 8.5. It is included here because the preparation of such an assessment involves a broad segment of the national public. This involvement and the public use of the assessment as an awareness vehicle may bring about public understanding of the program to process materials in space. The problems associated with the social impact assessment have been previously identified in Section 8.5. In this application, it is possible that positive outcomes of the assessment will be obscured by negative factors involved in preparing the assessment.

The third alternative involves three parts. First, the present head of the Materials Processing in Space Division of NASA's Office of Applications has suggested [Carruthers - 77] the formation of an industry advisory board to provide a communication channel between that division and the industrial community. There is now an interface with an advisory board representing the academic community. The use of both boards would bring about an improvement in program awareness. The Design Team suggests that the industry board include a member of two from the American Management Association and the U. S. Chamber of Commerce as well as members from the industrial materials processing community. It is intended that there be two-way communication between NASA and this industry advisory board.

The second part of the third alternative is the establishment of a broadly-based advisory board attached to the office of NASA's Associate Administrator for External Affairs. The function of this board would be to advise NASA on public relations. A diverse range of disciplines should be represented by the members of this board -- sociologist, political scientist, scientist, artist, aerospace

engineer, musician, science-fiction author, advertising executive. Interaction with this group on an annual or semi-annual basis may lead to the development of significant methods to achieve program awareness.

The third part of the third alternative is to identify the materials processing program with an established national goal such as the energy goal or a health-related goal.

RECOMMENDATION: The Design Team recommends the third alternative.

Here are some other ways of informing the public. These ideas have been discussed and thought worthy of trying at least once.

- ° Fly an artist, composer, poet, theologian, philosopher student or mother on one of the early Shuttle flights as an observing passenger. Ask the observer to relate impressions of the experience to the nation through that person's medium of expression.[Harkins - 77].
- ° Fly a 3-man team of social scientists who then would freely think about the social problems of space industrialization and/or how space activities might apply to the solution of social problems. The flight experience may stimulate their creative abilities.
- ° Publicize the fact that NASA has placed upon themselves depletion quotas for the annual consumption of various national resources.
- ° Appeal to the science-fiction community -- 400,000 people who can readily identify with a space related goal. NASA has not sought the help or counsel of this group.
- ° The extension of U. S. technology is frequently feared by other countries despite the long record of the U. S. to export new goods and services which are tremendously beneficial to recipient countries. The capability of Shuttle to act as a transporter of men routinely to and from space offers the U. S. the opportunity to fly "dedicated international" tourist flights. These flights could allow foreign countries to reward great diplomats, etc., for their service to the country. The flights would be restricted so that only people who made peaceful contributions to the country/world would be allowed. This approach of a dedicated flight would enhance world opinion of the U. S. space program and emphasize the peaceful aspects of space use.

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CHAPTER 8

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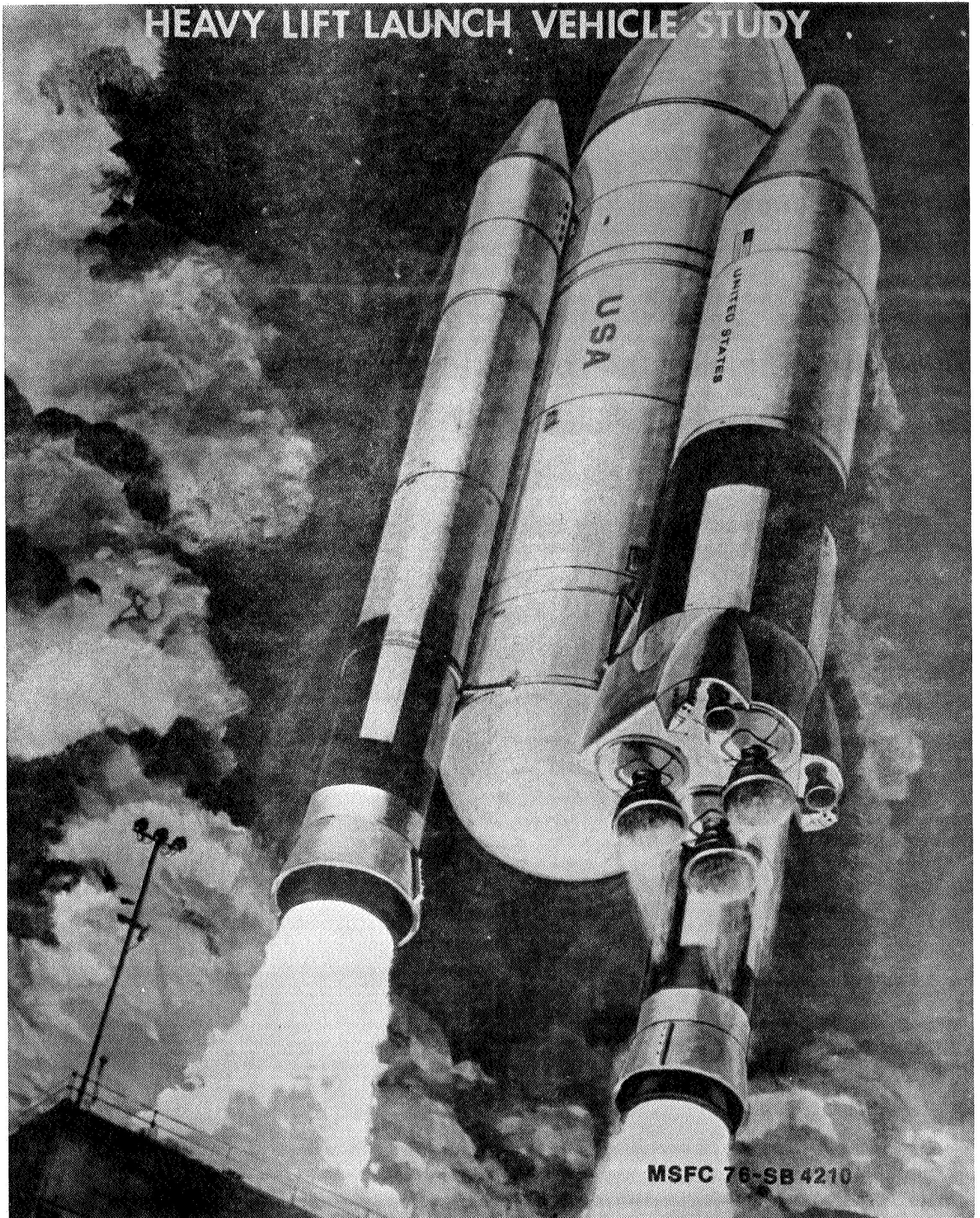
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HEAVY LIFT LAUNCH VEHICLE STUDY



CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

The plan for materials processing in space is based on the conclusion that there will be a materials processing era in space. The unique properties of space provide an opportunity for materials processing that may begin a new era in industrialization.

The following recommendations are the results of the summer systems study and are a consensus of the design team. Additional conclusions and recommendations may be found within the preceding chapters. These reflect the consensus of the responsible task group. The section of this report from which the recommendation came is noted for each item:

- ° Use existing airline agents and transportation system to facilitate the flow of materials from the user-industry to the launch site. 4.6
- ° Automate the orbiting processing facility initially and provide for later conversion to a man-tended mode. 4.6
- ° Organize the space station for commercial materials processing in a civil-maritime manner along the line of a fish processing factory ship. 4.6
- ° Emphasize the development of processes rather than the development of products. 5.1
- ° Include contingency planning as a budget line item. 5.7
- ° Modify the NASA five-year plan to:
 - Increase the time frame to 8 or 10 years.
 - Include a contingency planning section. 5.7
- ° Make a study to examine how to promote institutional coordination among the users of the Space Shuttle. 5.7
- ° Develop the processing facilities in space on a modular concept to maximize flexibility. 6.4
- ° Provide facilities which will encourage research by both large and small organizations with later provisions for user-owned processing modules. 6.4

- ° Increase the R&D budget for materials processing in space to \$120 million per year during the decade of the 80's. 7.5.1
- ° Establish a single ground-based research laboratory to support materials processing in space. 7.5.1
- ° Perceive, define, understand, and act upon the effect of the space industrialization program on the environment. 8.2.7
- ° Incorporate human resources accounting into space programs, treating personnel as capital assets rather than expenses. 8.3
- ° Plan for the consideration of the constraining effects of non-militarization policies in connection with the space industrialization programs. 8.4.3
- ° Plan to provide security in the area of industrial proprietary rights. 8.4.3
- ° Recommend that the United States investigate the establishment of an international space station. 8.4.3
- ° Plan the preparation of a social impact assessment for the program to process materials in space. 8.5
- ° Increase public awareness by:
 - Formation of an industry advisory board to the Materials Processing in Space Division within the NASA Office of Applications.
 - Formation of a broad-based advisory board on public relations attached to the NASA Associate Administrator for external affairs.
 - Identification of the materials processing in space with a national goal. 8.6

These recommendations - along with that part of NASA's present program which is consistent with these recommendations - form the basis of the system which will "describe the conceptual evolution, the institutional interrelationships and the basic physical requirements to implement materials processing in space."

This study has attempted to address some of the factors which will play an important role in future materials processing in space. While the study has not been exhaustive, it does identify numerous issues, both technical and nontechnical, which will affect the manner in which materials processing will develop. It is felt that with continued study and appropriate action on these issues, materials processing will become a significant factor in the industrialization of space.

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APPENDIX A (Chapter 3)

Future Space Objectives — 1980 to 2000

EARTH ORIENTED ACTIVITIES RESPONSIVE TO BASIC HUMAN NEEDS THEME 01: PRODUCTION AND MANAGEMENT OF FOOD AND FORESTRY RESOURCES Objective 011 — Global Crop Production Forecasting Objective 012 — Water Availability Forecasting Objective 013 — Land Use and Environmental Assessment Objective 014 — Living Marine Resource Assessment Objective 015 — Timber Inventory Objective 016 — Rangeland Assessment	THEME 07: EARTH SCIENCE Objective 071 — Earth's Magnetic Field Objective 072 — Crustal Dynamics Objective 073 — Ocean Interior and Dynamics Objective 074 — Dynamics and Energetics of Lower Atmosphere Objective 075 — Structure, Chemistry, and Dynamics of the Stratosphere Mesosphere Objective 076 — Ionosphere-Magnetosphere Coupling
THEME 02: PREDICTION AND PROTECTION OF THE ENVIRONMENT Objective 021 — Large-Scale Weather Forecasting Objective 022 — Weather Modification Experiments Support Objective 023 — Climate Prediction Objective 024 — Stratospheric Changes and Effects Objective 025 — Water Quality Monitoring Objective 026 — Global Marine Weather Forecasting	EXTRATERRESTRIAL ACTIVITIES RESPONSIVE TO INTELLECTUAL HUMAN NEEDS THEME 08: THE NATURE OF THE UNIVERSE Objective 081 — How did the Universe Begin? Objective 082 — How do Galaxies Form and Evolve? Objective 083 — What are Quasars? Objective 084 — Will the Universe Expand Forever? Objective 085 — What is the Nature of Gravity?
THEME 03: PROTECTION OF LIFE AND PROPERTY Objective 031 — Local Weather and Severe Storm Forecasting Objective 032 — Tropospheric Pollutants Monitoring Objective 033 — Hazard Forecasting from <i>In-Situ</i> Measurements Objective 034 — Communication-Navigation Capability Objective 035 — Earthquake Prediction Objective 036 — Control of Harmful Insects	THEME 09: THE ORIGINS AND FATE OF MATTER Objective 091 — What is the Nature of Stellar Explosions? Objective 092 — What is the Nature of Black Holes? Objective 093 — Where and How Were Elements Formed? Objective 094 — What is the Nature of Cosmic Rays?
THEME 04: ENERGY AND MINERAL EXPLORATION Objective 041 — Solar-Power Stations in Space Objective 042 — Power Relay via Satellites Objective 043 — Hazardous Waste Disposal in Space Objective 044 — World Geologic Atlas	THEME 10: THE LIFE CYCLE OF THE SUN AND STARS Objective 101 — What are the Composition and Dynamics of Interstellar Matter? Objective 102 — Why and How Does Interstellar Dust Condense Into Stars and Planets? Objective 103 — What are the Nature and Cause of Solar Activity? Objective 104 — Corona and Interplanetary Plasma Objective 105 — What is the Ultimate Fate of the Sun?
THEME 05: TRANSFER OF INFORMATION Objective 051 — Domestic Communications Objective 052 — Intercontinental Communications Objective 053 — Personal Communications	THEME 11: EVOLUTION OF THE SOLAR SYSTEM Objective 111 — What Process Occurred During Formation of the Solar System? Objective 112 — How do Planets, Large Satellites, and Their Atmospheres Evolve? Objective 113 — How Can Atmospheric Dynamics be Quantified? Objective 114 — What are the Origin and History of Magnetic Fields?
THEME 06: USE OF ENVIRONMENT OF SPACE FOR SCIENTIFIC AND COMMERCIAL PURPOSES Objective 061 — Basic Physics and Chemistry Objective 062 — Materials Science Objective 063 — Commercial Inorganic Processing Objective 064 — Biological Materials Research and Application Objective 065 — Effects of Gravity on Terrestrial Life Objective 066 — Living and Working in Space Objective 067 — Physiology and Disease Processes	THEME 12: ORIGINS AND FUTURE OF LIFE Objective 121 — How Did Life on Earth Originate? Objective 122 — Is There Extraterrestrial Life in the Solar System? Objective 123 — What Organic Chemistry Occurs in the the Universe? Objective 124 — Do Other Stars Have Planets? Objective 125 — Can We Detect Extraterrestrial Intelligent Life?

APPENDIX B (Section 5.2)

NASA FINANCIAL SUMMARY (in millions of dollars)

Fiscal Year	Total Approp.	Total Direct Obligations	OUTLAYS			
			Total	(R&D)	Const. of Facilities	Research and Prog. Mgmt.
1959	330.9	298.7	145.5	34.0	24.8	86.7
1960	523.6	486.9	401.0	255.7	54.3	91.0
1961	966.7	908.3	744.3	487.0	98.2	159.1
1962	1,825.3	1,691.7	1,257.0	935.6	114.3	207.1
1963	3,674.1	3,448.4	2,552.4	2,308.4	225.3	18.7
1964	5,100.0	4,864.8	4,171.0	3,317.4	437.7	415.9
1965	5,250.0	5,500.7	5,092.9	3,984.5	530.9	577.5
1966	5,175.0	5,350.5	5,933.0	4,741.1	572.5	619.4
1967	4,968.0	5,011.7	5,425.7	4,487.2	288.6	649.9
1968	4,588.9	4,520.4	4,723.7	3,946.1	126.1	651.5
1969	3,995.3	4,045.2	4,251.7	3,530.2	65.3	656.2
1970	3,749.2	3,858.9	3,753.1	2,991.6	54.3	707.2
1971	3,312.6	3,324.0	3,381.9	2,630.4	43.7	707.8
1972	3,310.1	3,228.6	3,422.9	2,623.2	50.3	749.4
1973	3,407.7	3,154.0	3,315.2	2,541.4	44.7	729.1
1974	3,039.7	3,122.4	3,256.2	2,421.6	75.1	759.5
1975	3,231.1	3,265.9	3,266.5	2,420.4	85.3	760.8
1976	3,551.8	3,604.8	3,669.0	2,748.8	120.9	799.3
TQ	932.1*	998.6	951.4	730.7	25.8	194.9

TQ Transition Quarter

* Includes supplemental for RPM to cover October 1975 pay increases: \$16.8 for 1976 and \$7.1 for TQ

APPENDIX C (Sect. 6.4)

ANNOUNCEMENT OF OPPORTUNITY

The following is extracted from the NASA Announcement of Opportunity, NO. OA-77-3, "Materials Processing Investigations on Space Shuttle Missions."

The program for materials processing in space has supported activities and maintains current interests in all of the following technical areas where prospects have been identified for applications of space flight:

Biological Preparations

Electronic Materials

Metallurgical Processes

Glass and Ceramics

Physical Processes in Fluids

Chemical Processes

Electrochemical Processes

It is currently believed that the best prospects for useful and profitable applications are to be found in the biomedical and electronic areas, and, therefore, it is expected that experiments on the early STS missions will emphasize these areas. However, it is recognized that the most strikingly useful applications of scientific knowledge generally result from research that attains a high degree of excellence in its own right. Therefore, proposals responding to this solicitation will be judged primarily on their scientific and technical merits as well as the contributions they promise to make toward specific applications.

Since the earliest opportunities for systematic experimentation aboard the Space Shuttle will come in 1979 - 81, appropriate projects for this program will comprise investigations with relatively long-range objectives to be pursued by a mixture of research done on the ground and experiments performed in space. The objectives of each investigation should comprise intended accomplishments in the investigator's scientific or technical field and must be sufficiently specific and definite so that their degree of attainment can be demonstrated directly by physical evidence. Each investigator must adopt objectives that are important enough to justify his investigation's share of the total program cost.

APPENDIX D (Sect. 6.4)

SKYLAB EXPERIMENTS

(SELECTED) [Stuhlinger - 75]

1. Exposed materials under formation to a state of freedom from gravitational force.

2. Major topics of research included:

- ° Crystal formation from melts
- ° Crystal formation from vapors
- ° Alloy formation from components of different densities
- ° Homogeneity of dopant distribution in semiconductors
- ° Diffusion in liquid metals
- ° Solidification of molten metals

All of the above studies involved controlled heating and subsequent cooling of samples.

3. Some of the more significant experiments that were performed aboard Skylab are:

- ° Melting of indium antimonide and containerless resolidification resulting in a very homogeneous single crystal with few lattice defects and with exceptionally smooth surface [Walter - 74].
- ° Vaporization and cooling of germanium selenide resulting in crystals which were ten times as large as earth-grown crystals. The crystal surface was virtually free of defects. The deposition rate was also exceedingly high [Wiedemeier - 74].
- ° Recrystallization of indium antimonide doped with tellerium resulted in very homogeneous crystals.
- ° Gold-germanium mixtures, when melted and solidified under zero gravity showed very fine and uniform dispersion. Small

areas were found which represent a composite not formed under gravity, perhaps a new alloy or compound.

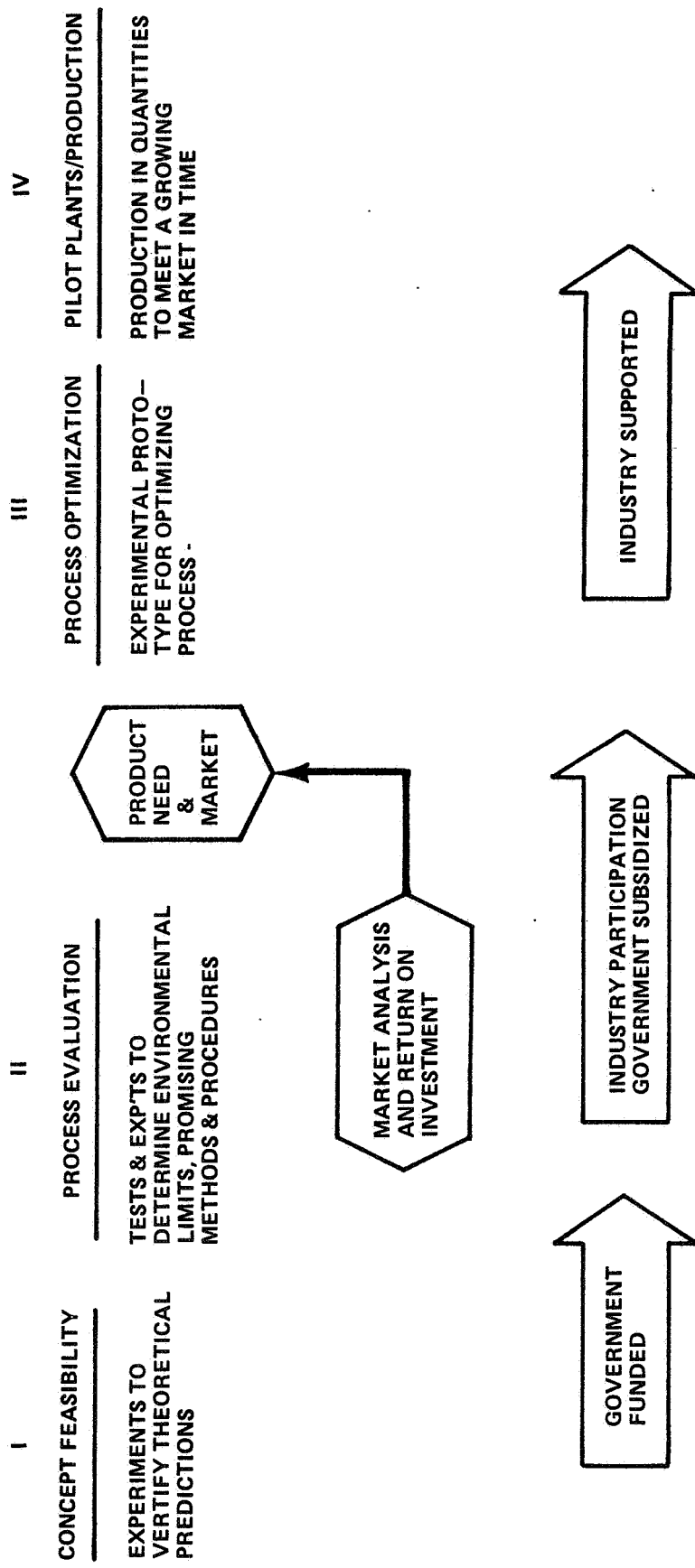
- Very thin films of vapor deposited gold-germanium showed superconductivity [Reger - 74].

4. The implications of these experiments are:

- Semiconductors will in all probability form crystals of unprecedented size and homogeneity when they are allowed to solidify under zero gravity without wall contact.
- The uniformity of space-grown crystals is superior to that of earth-grown crystals.
- New alloys or compounds may be produced, including new superconductors with superior properties and higher strength permanent magnets.
- More homogeneous lattice structure leads to stronger materials with more desirable electrical properties.
- Human cells can be studied alive outside of the body (due to lack of thermal stirring and sedimentation).
- High strength eutectic alloys can be solidified in space leading to more efficient, longer lasting turbine blades.
- Improved glasses and ceramics for better lasers might be produced.

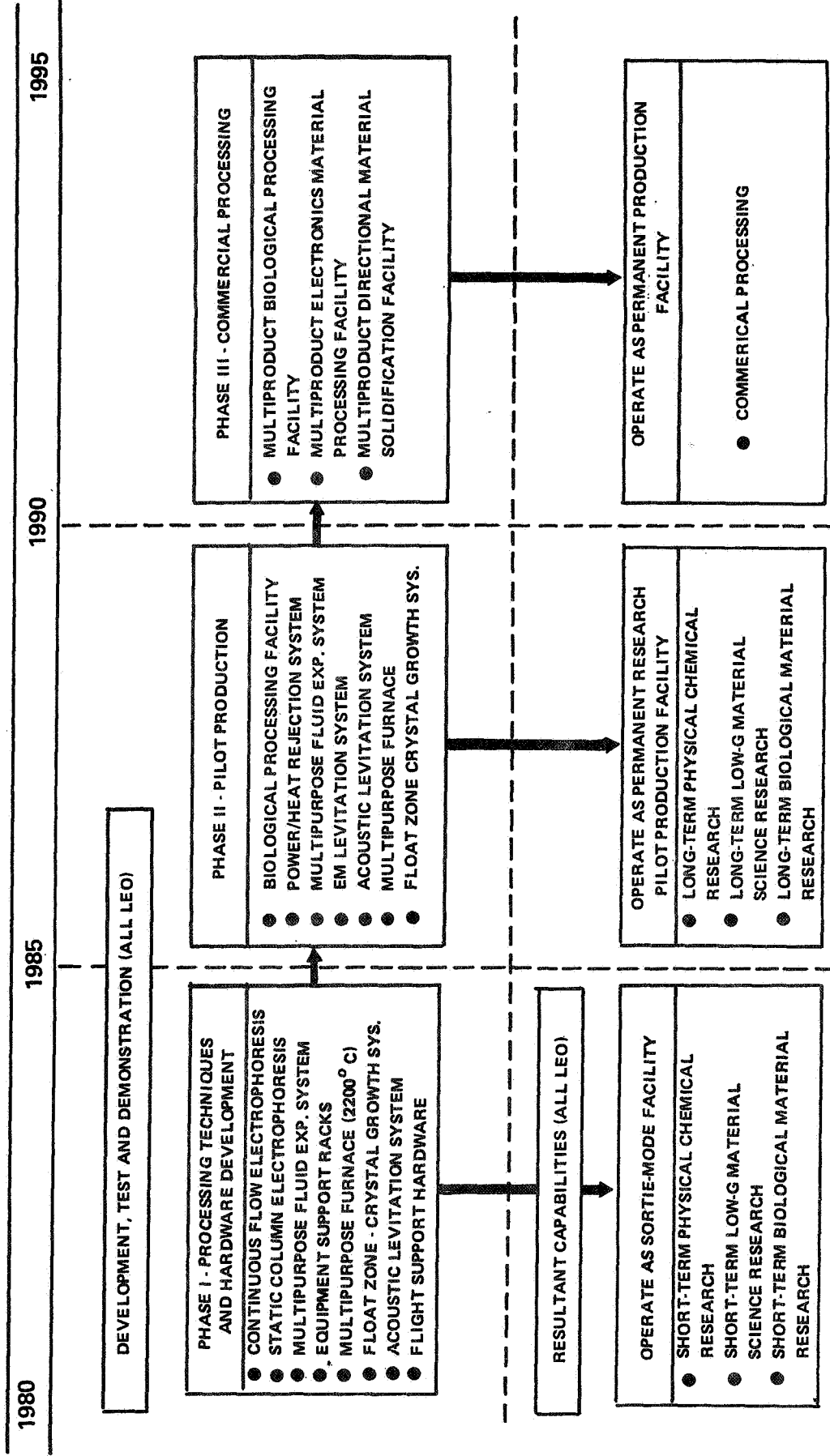
APPENDIX E (Section 6.3.5)

SPACE PROCESSING PRODUCT EVALUATION



APPENDIX F (Section 6.3.5)

SPACE PROCESSING AND MANUFACTURING (DEVELOPMENT PLAN)



SPACELAB EXPERIMENTAL LIST

MATERIAL SCIENCE FACILITY EXPERIMENTS

LEVITATION MELTING AND SOLIDIFICATION OF IMMISCIBLE ALLOYS

SOLIDIFICATION OF TECHNICAL ALLOYS

SKIN TECHNOLOGY, UNIDIRECTIONAL SOLIDIFICATION

VACUUM BRAZING

EMULSION AND DISPERSION OF ALLOYS

REACTION KINETICS IN GLASS

COMPOSITES (ME-GLASS)

METALLIC EMULSIONS A1PB

FIBRE AND PARTICLE COMPOSITES

BUBBLE REINFORCED MATERIALS

NUCLEATION BEHAVIOUR OF AG-GE

SOLIDIFICATION OF NEAR MONOTECTIC ZNP B ALLOYS

DENDRITE GROWTH AND MICRO-SEGREGATION

COMPOSITES WITH SHORT FIBRES AND PARTICLES

UNIDIRECTIONAL SOLIDIFICATION OF AL-ZN, AL-A12CU,

AG-GE EUTECTICS

BRIDGEMAN GROWTH OF LEAD TELLURIDE

UNIDIRECTIONAL SOLIDIFICATION OF INSB-NISH

SEE HIGH TEMPERATURE GRADIENT FURNACE

GAS ZONE CRYSTALLISATION OF SI SPHERES

BRIDGEMAN GROWTH OF CDTE

TREVELLING HEATER GROWTH OF III-V COMPOUNDS (INSB)

SEE HIGH TEMPERATURE GRADIENT FURNACE

UNIDIRECTIONAL SOLIDIFICATION OF CAST IRON

OSCILLATION DAMPING OF A LIQUID IN NATURE LEVITATION

KINETICS OF SPREADING OF LIQUIDS ON SOLIDS

FREE CONVECTION IN LOW GRAVITY

CAPILLARITY SURFACES IN LOW GRAVITY

COUPLED MOTION OF LIQUID-SOLID SYSTEMS IN NEAR ZERO-G

FLOATING ZONE STABILITY IN ZERO-G

ORGANIC CRYSTAL GROWTH

GROWTH OF MANGANESE CARBONATE

GROWTH OF PROTEINS

SELF AND INTERDIFFUSION IN LIQUID METALS

ELECTROLYSIS UNDER ZERO-G

ELECTROLYTIC DEPOSITION

GROWTH OF HG12 SINGLE CRYSTALS

CAPILLARITY EXPERIMENT

ADHESION OF METALS, UHV CHAMBER

APPENDIX H (Section 6.5)

BIOLOGICAL MODULE

H1.1 INTRODUCTION AND SUMMARY

The Biological Module would be dedicated to basic research activities in the immediate areas of biochemistry, biomedicine, bioengineering, and the life sciences. Life sciences has been defined in this study as those activities which focus their attention on the health and well-being of human beings while in the space environment, (i.e., respiration, cardiac functioning, etc.).

The Biological Module must be conceived and developed so as to present maximum potential for being of great and direct benefit to people, by virtue of improving health and well being, by developing research methodologies which will prevent their state of good health from deteriorating and/or other separate but related spheres of biological activities.

To this end, then, the Biological Module must be dedicated to the following specific ends:

- ° It must be dedicated to basic biological research.
- ° It must be highly efficient, macroscopically effective, and philosophically and functionally practical.
- ° It must be developed, conceptually but with fabrication valuing, at minimum/nominal costs ratios.

As such, the conceptual design approach undertaken during the Biological Module study considered those concepts which have already been studied, planned, or conceived, and are currently being planned, are under study or development, and/or have been abandoned.

The study may be at least partially summarized by stating that the entire concept of the Biological Module has been studied in exhaustive detail by NASA and their contractors in the past. Some of the current programs, along with planned and abandoned programs and studies are briefly described under Section H1.2

H1.2 EXISTING BIOLOGICAL MODULE CONCEPTS AND STUDIES

There are a variety of essentially biological plans and concepts which are existent and/or are in the planning stage. As has been indicated earlier, the entire conceptual design of a Biological Laboratory or Module in space has been exhaustively studied, with some of the earlier effects initiating back in the 1960's, and more intensely within the last six years. Several of these programs/studies/concepts are briefly described.

H1.2.1 THE NASA-GENERAL DYNAMICS, CONVAIR STUDY

This initially low level effort consisted of a macroscopic overview of the feasibility of conceptually designing an orbiting Life Sciences and Payload Definition and Integration module. The early efforts were devoted to sorting and identifying significant, higher-priority biological research functions and tasks. They also developed layouts and preliminary conceptual designs of several potential payloads for the accomplishments of the selected life sciences research to be engaged in in space. NASA management was presented with the contractor's findings [General Dynamics - 73; General Dynamics - 71]. (See Exhibit H-1) These references represent the beginning of a series of studies undertaken by this NASA contractor team. Extensions of the studies are presented in references [General Dynamics, Vol. I - IV - 74; General Dynamics, Cost - 74; General Dynamics, Definition - 75]. The efforts defined four baseline preliminary conceptual design payloads, termed: the Maxi-Max, or maximum laboratory; the Maxi-Nom, or maximum nominal laboratory; the Mini-30, or minimum 30-day (Shuttle) payload; and the Mini-7, or minimum 7-day (Shuttle) payload [General Dynamics - 73].

H1.2.2 THE NASA-McDONNELL DOUGLAS STUDY

This effort consisted of two phases: an early phase concerned with conceptual studies in the late 1960's which were not vigorously pursued at that time due to the predominance of the space effort being devoted to the Saturn V (Apollo) program [McDonnell-Douglas - 70].

The more vigorous efforts undertaken by the NASA-McDonnell Douglas team were much more recent, (within the last three to five years), and represented a broadening of the NASA-General Dynamics, Convair Study reported immediately above. This latter team did not abandon the studies, but rather, they were broadened to extend to a second contractor (McDonnell-Douglas) to afford more definitive coverage in both depth and breadth of the conceptual evolution of the Life Sciences Laboratory which had assumed a more prominent hierarchical priority upon completion of the Saturn V program.

H1.2.3 THE NASA BIOMEDICAL EXPERIMENTS SCIENTIFIC SATELLITE (BESS)

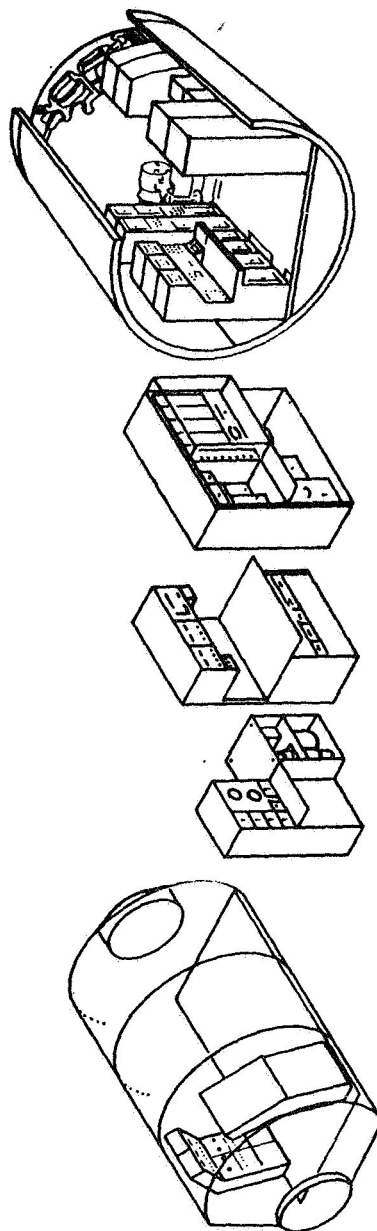
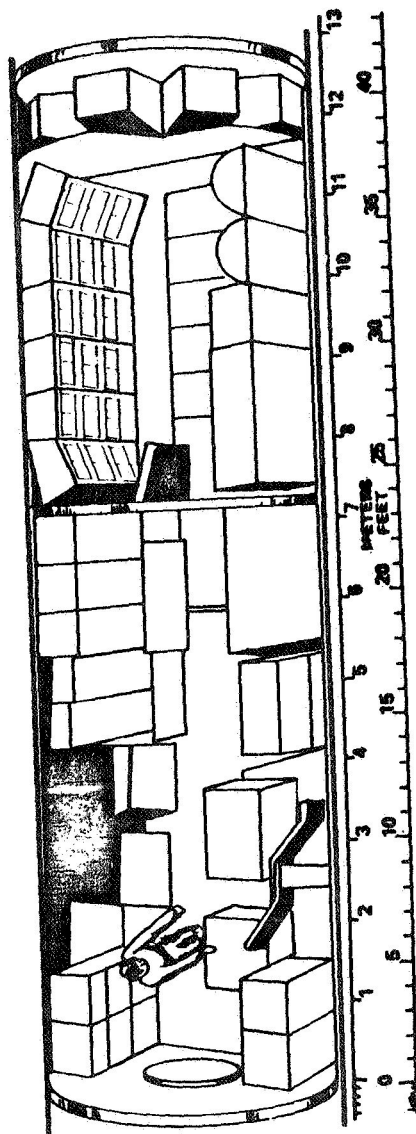
The BESS program is essentially devoted to studying the effects on relatively long-term weightlessness on the human organism. The data gathered will be utilized in future programs evolving into the design of large space stations, and the manned exploration of the solar system. The BESS program has been active for approximately five years and has evolved to being currently under contract with the Systems Design Study group at General Electric, Valley Forge Space Division [Berry - 76].

H1.2.4 THE NASA-McDONNELL DOUGLAS ASTRONAUTICS COMPANY STUDY

The program concentrates on the overall acquisition, staging, and integration of payload elements, together with program implementation methods and mission support requirements. Time based in the Shuttle era, the plans evolve about five basic configurations, ranging from dedicated

Exhibit H-1

NASA BIOLOGICAL MODULE



SUPPORT MODULE (SPACELAB) + BIOLOGICAL LABORATORY EQUIPMENT = BIOLOGICAL LABORATORY MODULE

H-4

H1.2.8 THE NASA EUROPEAN SPACE AGENCY (ESA) PROGRAM

ESA Spacelab will contain "some" biological test efforts at a relatively "simplistic" approach, initially utilizing only a few basic monitoring instruments. The ESA Spacelab has been designed with a removable end cone enabling the unit to operate from a dedicated, to a mixed-discipline, or partially-shared flight mission.

H1.2.9 THE NASA PLANNING FOR LIFE SCIENCES RESEARCH IN SPACE PROGRAM

In April 1975, NASA HQ extended an invitation to participate in the NASA Life Sciences Program in space to the scientific community on a national scale. The expressed intent was "... to develop general research objectives and spacecraft laboratories capabilities which represent the desires of the potential principal investigators." Both manned and unmanned life sciences missions are included for implementation in the 1980's decade with Shuttle utilization [Mallory - 76].

Dr. Sherman Vinograd and Mr. Robert Dunning of NASA HQ have advised that NASA is updating and revising this invitation and will issue the new one this Fall [Vinograd, Dunning - 77].

Dr. Mary Frances Thompson confirmed that the professional biological community has intense interest in this program [Thompson - 77].

Dr. Patricia Horner, the Associate Director of the Alliance for Engineering in Medicine and Biology, Bethesda, Maryland, also confirms widespread interest throughout numerous disciplines in the scientific community. (The Alliance represents professional associations in a wide spectrum of professional scientific disciplines in virtually all major areas).

Dr. Stanley Deutsch (NASA HQ), Associate Director of this program, confirms that this program is being vigorously pursued and that proposals continue to be received.

In other telecons with "space-oriented" scientific professionals, (Biologists, etc.), a high degree of interest was apparent. In still other telecons with "non-space-oriented" scientific professionals, who generally had not heard of the program and were only vaguely aware of the Shuttle program, the idea seemed appealing.

H1.2.10 OTHER PROGRAMS

- ° NASA HQ - ESRO Life Sciences Program. The European Space Research Organization (ESRO) is quasi-allied with ESA. The group concentrates on basic research to be performed on ESA's Spacelab.
- ° NASA Langley Research Center ATL Program. The Advanced Technology Lab (ATL) is Langley's low-level input in the Life Sciences Program.

missions, including primates and small vertebrates, to small carry-on shared-module investigations [McCollum - 75]. Some of the configurations are not unlike those described under Section H1.2.1.

H1.2.5 THE McDONNELL DOUGLAS STUDY

The study essentially consisted of identifying leading biomedical research centers across the nation, with outstanding programs for visiting scientists participation. The study revealed a wide and often unique variety of approaches and special problems. Some results of this study are being investigated for marine applications as well [Kelton - 75].

H1.2.6 THE CORE PROGRAM: COMMON OPERATIONAL RESEARCH EQUIPMENT

Dr. Sherman Vinograd, (NASA HQ) advises via telecon that NASA is essentially committed to the CORE Program which emphasizes the of common research equipment to carry on a variety of research tasks. Essentially, not several pieces of equipment to do separate tasks, but rather, one such piece of equipment which would be capable of multiple tasks [General Dynamics, Vol. 1-4, - 73]. This basic approach was very much in evidence in the General Dynamics, Convair study effort reported under Section H1.2.2.

H1.2.7 THE NASA SKYLAB PROGRAM

The flights of the Skylab vehicle did include a number of Life Sciences research missions, as well as a limited amount of tissue/cell culturing efforts, (in addition to some research efforts dealing with Solar Physics, Earth Observations, Astrophysics, Materials Science and Manufacturing in Space, and in Engineering and Technology Experiments). The biological research experiments were strained primarily to what we have earlier defined as those activities primarily concerned with the health and well-being of human organisms in space environment. These life sciences experiments included mineral balance, bioassay of body fluids, specimen mass measurement, bone mineral measurement, lower body negative pressure, vectrocardiogram, cytogenic studies of the blood, human immunity, in-vitro aspects, blood volume and red cell life, red blood cell metabolism, special hematologic effect, human vestibular function, sleep minitoring, time and motion study, metabolic activity, body mass measurement, low-g effects on single human cells, circadian rhythm of pocket mice and of the vinegar gnat.

Unfortunately, the experiments dealing with human cells in the low-g environment were still being re-evaluated at the time of publication of the results for the other experiments [NASA - 71], and were not available. Subsequent conversation with Mr. Robert Dunning, (NASA HQ) has resulted in his confirming the fact that such re-evaluations have now been completed.

- NASA-MSFC Life Sciences Mini-Lab. The Mini-lab is not a program but rather a definition of type/size of payload missions.
- THE NASA-MSFC Free-Flying Teleoperator Program. This is a current program and represents the MSFC's applications program in the field of robotics. Where JSC has concentrated in the Remote Manipulator System (RMS) for the Shuttle manipulator arm, and JPL has concentrated in the planetary roving vehicle, artificial intelligence and distant remote control area, MSFC has placed its emphasis on the Free-Flying Teleoperator, (FFT). It will have the capability of being operated by a crewman, in manned vehicles, and remotely from ground-control for unmanned systems. Anticipated uses of the FFT include applications in handling/assembling parts and sub-assemblies for building structures in space; for satellite retrieval missions; and, most recently, is being considered for a Skylab re-boost operation wherein the FFT would effectuate strap-on propulsion units to accomplish the mission.
- Miscellaneous Program studies. These programs include:
 - Biosatellite Studies: three flights were planned. One three-day flight was successfully completed; a second, with primate, was terminated early; and a third was deleted.
 - Apollo Applications Program: concerned with further utilization of Apollo mission capabilities.
 - Support Research and Technology Program: responsible for early program studies, feasibilities and development. Administered by the Aeronautics and Space Technology Office in Washington, D. C.
 - There are, in addition, several other offices and programs directly concerned with early and developmental identification and definition of related biological and life sciences programs.

H1.3 THE CURRENT STATUS

At the conclusion of the referenced study programs which were primarily under MSFC management, the Biological Module conceptual design program expanded to both Johnson Space Center and Ames Research Center, as NASA HQ continued, but in a more active role.

Essentially, the current efforts include an evolution of ground-simulation of space research future tasks, and have already involved MSFC's Concept Verification Test facilities and JSC's ground-simulation facilities. Three ground-simulation tests have been performed with the most recent terminating in June 1977.

It seems that JSC has the responsibility for integrating the whole of the life-science laboratory program and is managing it primarily from an applied research and operational capability approach. ARC's responsibilities are founded heavily on basic research, specimen selection and care, and related support equipment and instrumentation.

Essentially all of the contract studies discussed under the previous section, and the efforts indicated in the above paragraphs have had their origins in and are extensions of the NASA "Blue Book", [NASA - 71], and subsequent revisions.

APPENDIX I (Section 8.4)

TABLE OF TREATIES

1. Sweden-Denmark: Peace Treaty, Kiel, 14 January 1814 (Martens: Nouveau Recueil de Traites, Vol. I, p.666)
2. United States-Russia: Convention Ceding Alaska, 30 March 1867 (Treaties between the United States and other Powers, Vol. II, p.1521)
3. Chile-Argentina: Treaty of Delimitation, 23 July 1881 (Martens: Nouveau Recueil de Traites, II, Vol. XII, p.491)
4. Convention on the Rights and Duties of Neutral Powers in Maritime War, The Hague, 18 October 1907 (Higgins: The Hague Peace Conferences, 1909, p.445)
5. Convention Relating to the Regulation of Aerial Navigation, Paris, 13 October 1919 (League of Nations, Treaty Series, No.297, Vol. XI, p.174)
6. Treaty Concerning the Archipelago of Spitsbergen, Paris, 9 February 1920 (League of Nations, Treaty Series, No.41, Vol. II, p.8)
7. United Kingdom-United States: Convention Respecting the Regulation of Liquor Traffic, 23 January 1924 (League of Nations, Treaty Series, No.681, Vol. XXVII, p.182)
8. Proces-Verbal Relating to the Rules of Submarine Warfare, London, 6 November 1936 (League of Nations, Treaty Series, No.4025, Vol. CLXXIII, p.353)
9. Atlantic Charter, 14 August 1941 (American Journal of International Law, 1941, Suppl. p.191)
10. Convention on International Civil Aviation, Chicago, 7 December 1944 (American Journal of International Law, 1945, Suppl. p.111)
11. Charter of the United Nations, San Francisco, 26 June 1945 (United Nations Office of Public Information, 1965, pp.91)
12. Convention on the Territorial Sea and the Contiguous Zone, Geneva, 29 April 1958 (Cmnd.584, Misc. 1958/15, pp.51)
13. Convention on the High Seas, Geneva, 29 April 1958 (Cmnd.584, Misc. 1958/15, pp.51)
14. Convention on the Continental Shelf, Geneva, 29 April 1958 (Cmnd.584, Misc. 1958/15, pp.51)
15. Antarctic Treaty, Washington, 1 December 1959 (Cmnd.913, Misc. 1959/21, pp.12)
16. Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, Moscow, 5 August 1963 (United Nations Treaty Series No. I:6964, Vol. 480, p.43)
17. Convention on Offences and Certain Other Acts Committed on Board Aircraft, Tokyo, 14 September 1963 (American Journal of International Law, 1964, p.566)
18. European Agreement for the Prevention of Broadcasts Transmitted from Stations Outside National Territories, Strasbourg, 20 January 1965 (American Journal of International Law, 1968, p.814)
19. Convention on Facilitation of International Maritime Traffic, London, 9 April 1965 (International Legal Materials, Vol. 4, p.502)
20. Treaty on Principles governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies, London, Washington, Moscow, 27 January 1967 (Cmnd.3198, Misc. 1967/3, pp.7)
21. Convention on the Law of Treaties, Vienna, 23 May 1969 (Cmnd.4140, Misc. No.31 (1969), pp.39)

22. International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, Brussels, 29 November 1969 (Cmnd.4403, Misc. No.8 (1970), pp.33)
23. Convention for the Suppression of Unlawful Seizure of Aircraft, The Hague, 16 December 1970 (Cmnd.4577, Misc. No.5 (1971), pp.7)
24. Treaty on the Prohibition of the Emplacement of Nuclear Weapons and Other Weapons of Mass Destruction on the Sea-Bed and the Ocean Floor and in the Subsoil Thereof, London, Washington, Moscow, 11 February 1971 (Cmnd.4678, Misc. No.3 (1971), pp.12)
25. Convention for the Suppression of Unlawful Acts against the Safety of Civil Aviation, Montreal, 23 September 1971 (Cmnd.4822, Misc. No.26 (1971), pp.8)
26. Agreement on Prevention of Incidents at Sea, Moscow, 25 May 1972 (Keesing's Contemporary Archives, 1972, p.25313)

APPENDIX J (Section 8.4)

TREATY ON PRINCIPLES GOVERNING THE ACTIVITIES OF STATES IN THE EXPLORATION AND USE OF OUTER SPACE, INCLUDING THE MOON AND OTHER CELESTIAL BODIES

The States Parties to this Treaty,

Inspired by the great prospects opening up before mankind as a result of man's entry into outer space,

Recognizing the common interest of all mankind in the progress of the exploration and use of outer space for peaceful purposes,

Believing that the exploration and use of outer space should be carried on for the benefit of all peoples irrespective of the degree of their economic or scientific development,

Desiring to contribute to broad international co-operation in the scientific as well as the legal aspects of the exploration and use of outer space for peaceful purposes,

Believing that such co-operation will contribute to the development of mutual understanding and to the strengthening of friendly relations between States and peoples,

Recalling resolution 1962 (XVIII), entitled "Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space", which was adopted unanimously by the United Nations General Assembly on 13 December 1963,

Recalling resolution 1884 (XVIII), calling upon States to refrain from placing in orbit around the earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction or from installing such weapons on celestial bodies, which was adopted unanimously by the United Nations General Assembly on 17 October 1963,

Taking account of United Nations General Assembly resolution 110 (II) of 3 November 1947, which condemned propaganda designed or likely to provoke or encourage any threat to the peace, breach of the peace or act of aggression, and

considering that the aforementioned resolution is applicable to outer space,

Convinced that a Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, will further the Purposes and Principles of the Charter of the United Nations,

Have agreed on the following:-

Article I

The exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.

Outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.

There shall be freedom of scientific investigation in outer space, including the moon and other celestial bodies, and States shall facilitate and encourage international co-operation in such investigation.

Article II

Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.

Article III

States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international co-operation and understanding.

Article IV

States Parties to the Treaty undertake not to place in orbit around the earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, instal such weapons on celestial bodies, or station such weapons in outer space in any other manner.

The moon and other celestial bodies shall be used by all States Parties to the Treaty exclusively for peaceful purposes. The establishment of military bases,

installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration of the moon and other celestial bodies shall also not be prohibited.

Article V

States Parties to the Treaty shall regard astronauts as envoys of mankind in outer space and shall render to them all possible assistance in the event of accident, distress, or emergency landing on the territory of another State Party or on the high seas. When astronauts make such a landing, they shall be safely and promptly returned to the State of registry of their space vehicle.

In carrying on activities in outer space and on celestial bodies, the astronauts of one State Party shall render all possible assistance to the astronauts of other States Parties.

States Parties to the Treaty shall immediately inform the other States Parties to the Treaty or the Secretary-General of the United Nations of any phenomena they discover in outer space, including the moon and other celestial bodies, which could constitute a danger to the life or health of astronauts.

Article VI

States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty. When activities are carried on in outer space, including the moon and other celestial bodies, by an international organization, responsibility for compliance with this Treaty shall be borne both by the international organization and by the States Parties to the Treaty participating in such organization.

Article VII

Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the moon and other celestial bodies, and each

State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the moon and other celestial bodies.

Article VIII

A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth. Such objects or component parts found beyond the limits of the State Party to the Treaty on whose registry they are carried shall be returned to that State Party, which shall, upon request, furnish identifying data prior to their return.

Article IX

In the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty. States Parties to the Treaty shall pursue studies of outer space, including the moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose. If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the moon

and other celestial bodies, may request consultation concerning the activity or experiment.

Article X

In order to promote international co-operation in the exploration and use of outer space, including the moon and other celestial bodies, in conformity with the purposes of this Treaty, the States Parties to the Treaty shall consider on a basis of equality any requests by other States Parties to the Treaty to be afforded an opportunity to observe the flight of space objects launched by those States.

The nature of such an opportunity for observation and the conditions under which it could be afforded shall be determined by agreement between the States concerned.

Article XI

In order to promote international co-operation in the peaceful exploration and use of outer space, States Parties to the Treaty conducting activities in outer space, including the moon and other celestial bodies, agree to inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results of such activities. On receiving the said information, the Secretary-General of the United Nations should be prepared to disseminate it immediately and effectively.

Article XII

All stations, installations, equipment and space vehicles on the moon and other celestial bodies shall be open to representatives of other States Parties to the Treaty on a basis of reciprocity. Such representatives shall give reasonable advance notice of a projected visit, in order that appropriate consultations may be held and that maximum precautions may be taken to assure safety and to avoid interference with normal operations in the facility to be visited.

Article XIII

The provisions of this Treaty shall apply to the activities of States Parties to the Treaty in the exploration and use of outer space, including the moon and other celestial bodies, whether such activities are carried on by a single State Party to the Treaty or jointly with other States, including cases where they are carried on within the framework of international inter-governmental organizations.

Any practical questions arising in connexion with activities carried on by

international inter-governmental organizations in the exploration and use of outer space, including the moon and other celestial bodies, shall be resolved by the States Parties to the Treaty either with the appropriate international organization or with one or more States members of that international organization, which are Parties to this Treaty.

Article XIV

1. This Treaty shall be open to all States for signature. Any State which does not sign this Treaty before its entry into force in accordance with paragraph 3 of this Article may accede to it at any time.

2. This Treaty shall be subject to ratification by signatory States, Instruments of ratification and instruments of accession shall be deposited with the Governments of the United Kingdom of Great Britain and Northern Ireland, the Union of Soviet Socialist Republics and the United States of America, which are hereby designated the Depositary Governments.

3. This Treaty shall enter into force upon the deposit of instruments of ratification by five Governments including the Governments designated as Depositary Governments under this Treaty.

4. For States whose instruments of ratification or accession are deposited subsequent to the entry into force of this Treaty, it shall enter into force on the date of the deposit of their instruments of ratification or accession.

5. The Depositary Governments shall promptly inform all signatory and acceding States of the date of each signature, the date of deposit of each instrument of ratification of and accession to this Treaty, the date of its entry into force and other notices.

6. This Treaty shall be registered by the Depositary Governments pursuant to Article 102 of the Charter of the United Nations.

Article XV

Any State Party to the Treaty may propose amendments to this Treaty. Amendments shall enter into force for each State Party to the Treaty accepting the amendments upon their acceptance by a majority of the States Parties to the Treaty and thereafter for each remaining State Party to the Treaty on the date of acceptance by it.

Article XVI

Any State Party to the Treaty may give notice of its withdrawal from the Treaty

one year after its entry into force by written notification to the Depositary Governments. Such withdrawal shall take effect one year from the date of receipt of this notification.

Article XVII

This Treaty, of which the English, Russian, French, Spanish and Chinese texts are equally authentic, shall be deposited in the archives of the Depositary Governments. Duly certified copies of this Treaty shall be transmitted by the Depositary Governments to the Governments of the signatory and acceding States.

In witness whereof, the undersigned, duly authorised, have signed this Treaty.

Done in triplicate, at the cities of London, Moscow and Washington, the twenty-seventh day of January, one thousand nine hundred and sixty-seven.

APPENDIX K (Chapter 2)

STUDY ORGANIZATION

The Summer Faculty Engineering Systems Design Program is jointly sponsored by the National Aeronautics and Space Administration and the American Society for Engineering Education. The nineteen participants are teachers in science and engineering fields. Three of the group of 1977 had backgrounds in political science. The administrative staff was composed of staff members from the University of Alabama, and the Marshall Space Flight Center.

The purpose of the program was to apply the systems approach as described in Chapter 2 to problems of industrialization of space and in particular to materials processing in space.

A vital feature of the systems design program is the interaction among the Design Team participants. Meetings of large and small groups occurred on a daily basis. By this means, personal points of view and biases were exposed to group criticism and comment. A fundamental concern was that the Design Team focus on the study objective. Project and task group leadership positions were rotated to provide leadership experience for as many of the participants as possible.

The eleven-week program was divided into three equal interim periods. The first two periods were devoted largely to definition of an objective and its attendant requirements. Data gathering was broadly based. Speakers from government, industrial, and other sectors presented talks on the current status of materials processing in space (see Speakers Summaries, Appendix L). Many individuals, all over the U. S., were contacted by telephone, letter and, in some instances, by personal visits. The extensive resources of the Redstone Scientific Information Center, as well as current periodicals and professional journals, were searched for additional data.

In order to facilitate the collection and analysis of data, task groups were formed (see Exhibits K-1, K-2, K-3).

The organization of task groups was identical to the Design Team's assessment of the requirements of space industrialization: transportation, structures, functions, and institutions/management. By this division of labor, the Design Team sought to add depth to their study of the selected objective.

In the task groups, alternatives were discussed, debated, studied, and researched. The Transportation Task Group examined NASA's Space Transportation System, ground support facilities, and policies related to their use. Future transportation needs were also examined. The Structures Task Group examined physical plant design considerations for materials processing in space and construction problems that could be expected.

The Functions Task Group examined candidate products for materials processing and other areas in which the unique environment of an orbiting facility could be used. The Institutions/Management Group examined operational dimensions of a materials processing industry in space. They also examined legal, social and political issues that could be expected to influence space industrialization and materials processing.

As the study evolved into the second interim period, the greater importance of the institutions/management effort was recognized as a number of Design Team members joined that task group. The Structures and Functions Task Groups were merged (into Facilities) in recognition of the strong relationship of those two task group activities. The Transportation Task Group was continued. In addition an ad hoc task group on scenarios was formed to examine possible alternative paths of development of materials processing in space.

The third interim period showed additional evolution of the Design Team's thinking on materials processing in space. The final requirements were identified: Facilities, Funding, Organization, and Socio-Political Actions and Policies. Task groups were formed around these requirements and the final report reflects this organization also.

The dynamics of the group and its thinking is reflected in the organization and reorganization of the task groups; the movement of Design Team members between task groups also reflects these dynamics. The translation and analysis that occurs within the system design process is a product of the dynamic interaction of Design Team members and their ideas.

Exhibit K-1

ORGANIZATION CHART FOR FIRST INTERIM TERM, 1977 NASA/ASEE ALABAMA SYSTEM DESIGN PROGRAM

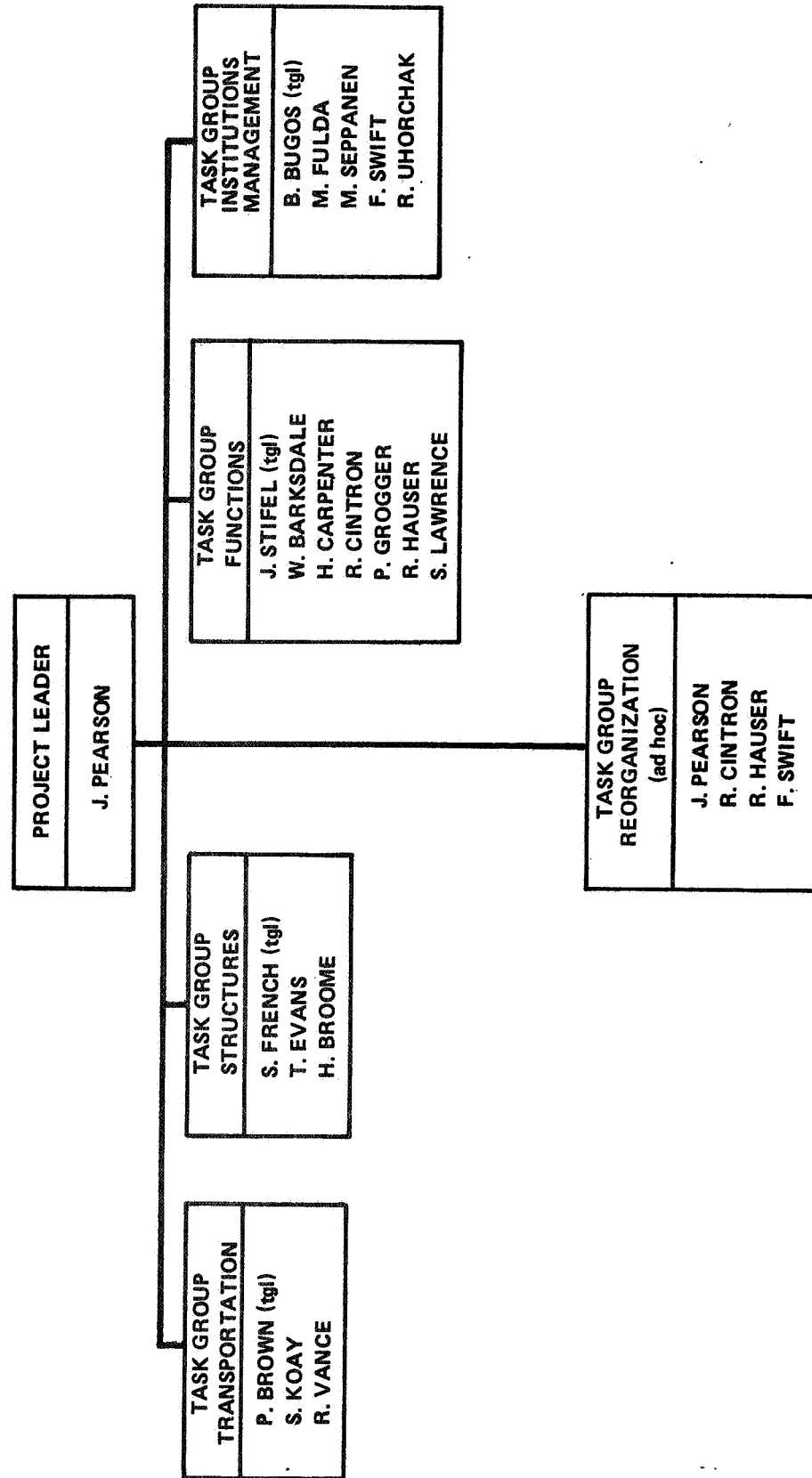


Exhibit K-2

ORGANIZATION CHART FOR SECOND INTERIM TERM, 1977 NASA/ASEE ALABAMA SYSTEM DESIGN PROGRAM

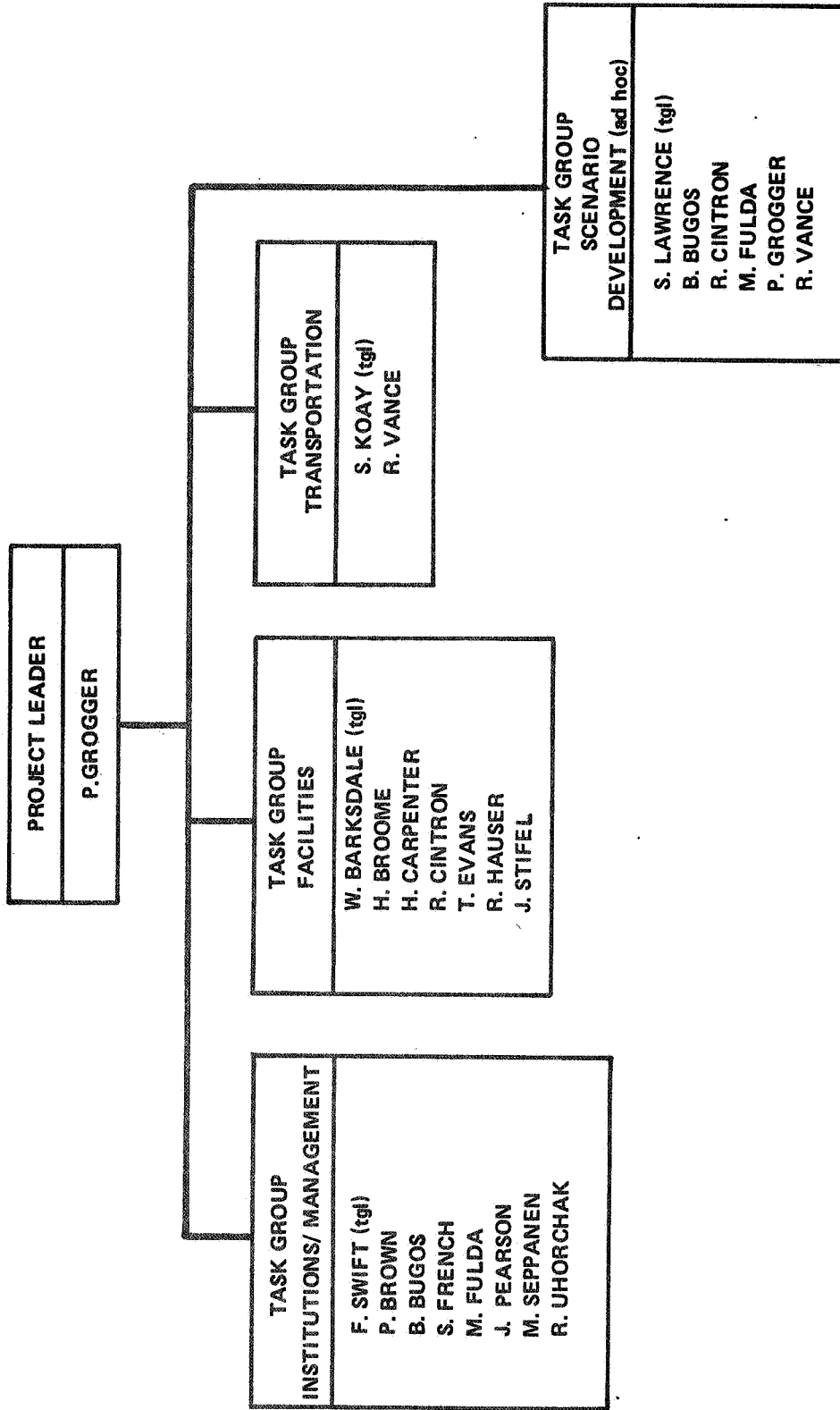
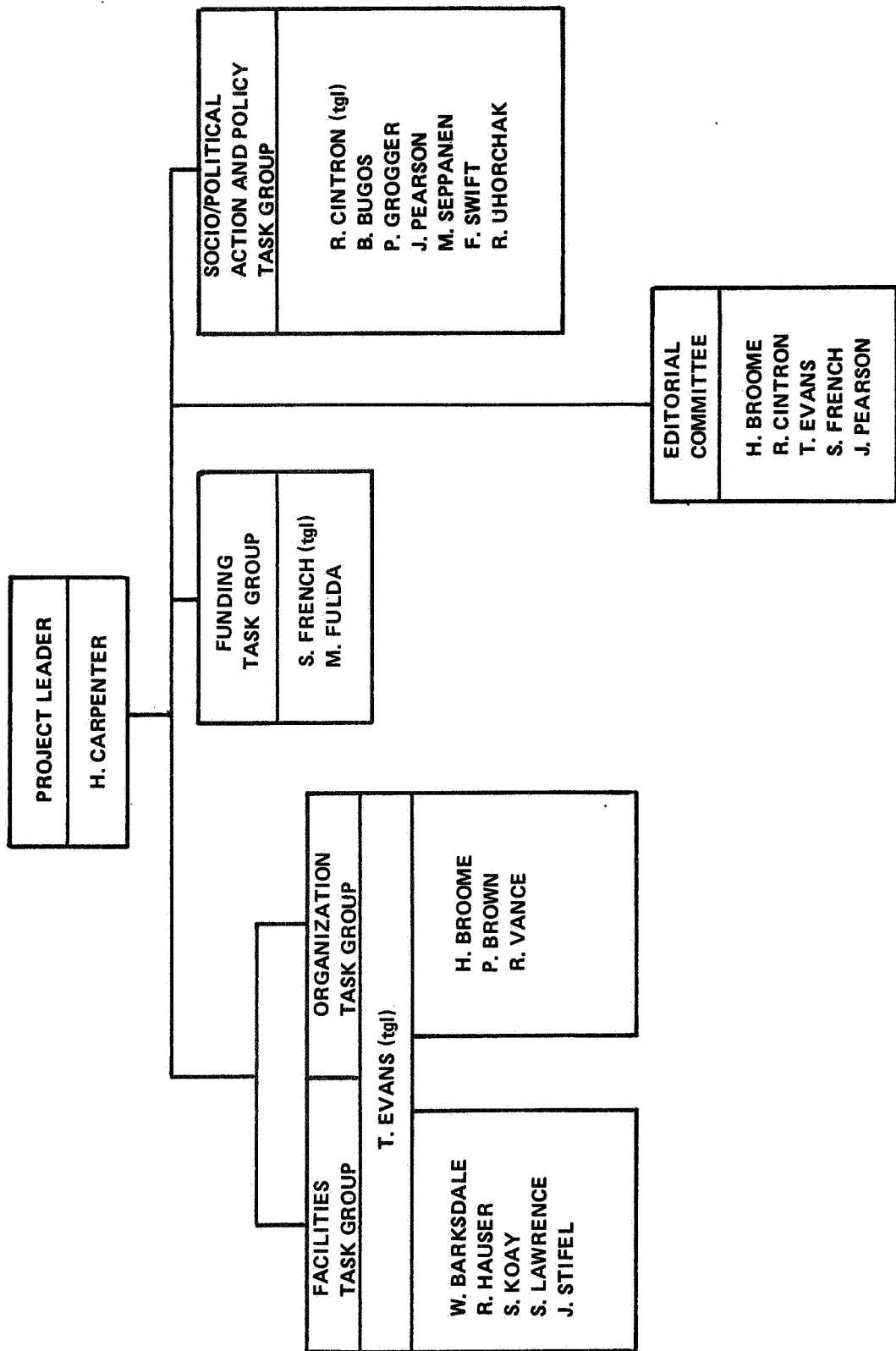


Exhibit K-3

ORGANIZATION CHART FOR THIRD INTERIM TERM, 1977 NASA/ASEE ALABAMA SYSTEM DESIGN PROGRAM



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APPENDIX L

SUMMARY OF SPEAKERS' SEMINARS

The many speakers who conducted seminars for the 1977 NASA/ASEE Faculty Fellowship Program in System Engineering Design at the Marshall Space Flight Center, which was directed by The University of Alabama, provided invaluable resource material for the 19 professors who participated in the program. The summaries given in this appendix are the paraphrased remarks of each speaker and in some instances the opinion or impressions of the faculty fellows are interwoven into the fabric of the summary. The summaries are arranged in chronological order.

SPACE PROCESSING AND INDUSTRIALIZATION-AN OVERVIEW

Charles A. Lundquist
Director, Space Sciences Laboratory
Marshall Space Flight Center, AL 35812

Dr. Lundquist presented the industrial objectives of space processing in a large perspective. This overview was organized as a spectrum of space activity areas ranging from a minimum to a maximum commercialization. Examples of each area are:

- . Fundamental Science - atomic clock experiment to verify Einstein's theory
- . Exploration - moon and planetary missions
- . Applied Research - spacelab experiments to study cloud droplets in the absence of gravity
- . Public Service - meteorological satellites
- . Commercial Applications - communication satellites

It was emphasized that the relevance of these areas does not necessarily increase with increasing commercialization, but that important commercial developments may result from investigation in any area.

The NASA branches with responsibility for the various areas of space activity are:

- . Office of Science Services (OSS) - fundamental science, exploration, applied research
- . Office of Applications (OA) - applied research, public service, commercial applications
- . Office of Space Flight (OSF) - all areas

The suggested areas for consideration in this summer project include applied research, public services, and commercial application, although the fundamental science area is also feasible. The only clear historic example of space industrialization is the communication satellite, as illustrated by the fact that of the 23 OSF launches this year, 17 are for paying commercial contractors with their own satellites. Hope was expressed that in the future space processing would provide a second example.

The promise of industrial material processing in space rests mainly on three facts; namely:

- . The effects of gravity can be reduced to the range 10^{-4} to 10^{-5} gravity, which greatly reduces gravity-driven convection currents and sedimentation. This has important implications in crystal growth, cell separation by electrophoresis (to produce urokinase), and the melting of caustic substances (wall effect).
- . A space vehicle moving at typically 8 km/s will leave a high vacuum wake as it sweeps out slower-moving gas molecules. This will allow experiments and manufacturing to be conducted in vacuums of about 10^{-14} T (H), 10^{-15} T (O), and 10^{-6} T (He), as compared to 10^{-11} to 10^{-12} achievable on earth.
- . The expanding need for new and better materials that permeates modern civilization makes the development and production of new materials in space very attractive.

The economic analysis of space processing was briefly discussed with the need to include human factors emphasized. It was also pointed out that NASA must develop product areas for which there are industrial customers who are eventually willing to assume the cost.

A range of problems for study by the summer project was next considered ranging over the areas of applied research, public services, and commercial applications:

- . Applied materials research
- . Orbiting research lab
- . Pilot plants
- . Production plants

It was suggested that either an idealized academic study be done, or else some realizable topic be selected that could perhaps be further developed and implemented in the near future by NASA. The latter choice was emphasized, and the following timetable was presented for the space shuttle program:

- . Six orbital test flights (OTF) around 1979
- . Three spacelab flights around 1980
- . A 25 KW solar power module for spacelab around 1983

The combination of spacelabs into a larger orbiting station was mentioned, as was the feasibility of using the large 27 ft. diameter shuttle fuel tank as a space station. Some possible specific topics mentioned were:

- . A module containing all manufacturing equipment could be designed to dock with the power module.
- . The problem of outfitting the orbiting shuttle fuel tank using tank fittings and scrap parts from other shuttle flights could be considered. Tanks could be connected together, and docked with the power module.

A question-and-answer period followed the presentation by Dr. Lundquist, and the following topics were mentioned:

- . The time-frame for manned space shuttle program, with a possible manned station by 1985 to be expanded over the 1980's.
- . Personnel for spacelab would require no particular flight qualifications (except for the flight crew!).
- . The NASA budget runs \$3 to 4 B/year, and is not anticipated to increase much during the shuttle program, but may be augmented by fees charged to industrial customers.
- . The subject of space burial was mentioned, then quickly laid to rest.
- . Nuclear processing, polymer processing, and slow centrifuge operations have all been considered by NASA.
- . The tradeoffs between automated and manned processing in space were mentioned.

A SYSTEMS APPROACH METHODOLOGY

Reginald I. Vachon
Professor, Department of Mechanical Engineering
Auburn University
Auburn, AL 36830

Dr. Vachon explained the systems approach methodology of problem solving that he and his associates have developed over a period of several years.

The necessity of interaction between the participants in this type of problem solving was stressed. The need to ignore personal differences and become a strong team member was emphasized several times. The objective for each member of the design team should be to work with every other member, developing a symbiotic relationship, to analyze every idea and to make the greatest impact possible in the time available with the information at hand.

One decision the design team must make is whether to take a narrow problem and solve it in depth or to take a wider view of a problem and generate a blueprint for its solution. Regardless of which approach is adopted, the final report is of value only if:

- o It is not dated when it is released.
- o It is concise and complete.

The team must guard against losing information that may seem inconsequential at the time but become important as the study progresses. The team should avoid prejudging an idea or solution. The need to document all data sources for ready retrieval was stressed.

Starting with an accepted definition of Systems Approach, Dr. Vachon expanded and modified the idea to the following:

Systems Approach is a multidisciplinary optimal solution or strategy to a complex problem to produce a functioning system or plan.

This definition is very encompassing in that it does not limit itself to a physical system and can be a strategy or a plan. In a broad sense it is the scientific method reduced to practice.

A 129 page handout written by Dr. Vachon and Dr. Lueg and which describes the methodology of the Systems Approach to problem solving is available to all.

In describing the methodology, Dr. Vachon emphasized the need for:

- o Defining the objective in simple terms
- o Good and complete documentation
- o Continuous communication

- o Sources of information that are varied and involve the highest levels of thinking and planning
- o A farsighted philosophy for defining and solving problems

In Summary:

The systems approach methodology include input, output, controls, and feedback. There are many tools for systems planning, but the methodology is the blueprint for action. The organization structure must be fluid.

Some of the traits necessary for systems planners and design team members are:

- o Affinity for systems thinking
- o Objective judgment
- o Imagination and creativity
- o Leadership
- o Communications

Dr. Vachon ended his talk with a challenge to the design team to work with a oneness that is necessary to produce results that are meaningful. In the future, when our results become incorporated into the space program, we can proudly say "we were there when it all started."

SPACE PROCESSING - PROGRAM OBJECTIVES

Robert S. Snyder
Chief, Separation Process Branch
Marshall Space Flight Center, AL 35812

Dr. Snyder indicated that it is not possible to predict the precise activities which will be carried out in space. Some likely possibilities have been identified and are being examined on the ground. The possibility of manufacturing products and of doing materials research in space are proceeding. The primary purpose of this group is to develop space separation technologies that have useful applications on earth. All of the possibilities identified to date present logistical problems, and it is clear that whatever is done must make use of the unique properties of the space environment. Because of these features, all early work will have to emphasize experiments.

One of the problems encountered in analyzing possibilities for processing in space is the characterization of the possibilities. The Materials Science and Manufacturing in Space Section has identified the following possibilities:

- Fluid effects
- Glasses
- Biologicals
- Semi-conductors
- Metals and alloys
- Shapes and structures

Some specific examples of various processes include:

- Semi-conductor Materials -- Transistors and resistors placed into integrated circuits have dimensions of the order of microns. When doped, the striations or variations in the semi-conductor material are of the same order. It is difficult to assure all resistors or all transistors have the same parameters. The striations may be caused by gravity and are of interest to the electronics industry.
- Biologicals -- Lymphocytes are part of the body's defense against disease. The differences between various kinds of lymphocytes have been identified only in recent years. There is some possibility that specific lymphocytes may be isolated using the low-g environment of space.

- Glasses -- Laser glass - laser fusion requires high-power glass lasers and there is some hope the lasers may be improved by manufacturing them in space.
- Glass Microspheres -- Laser fusion also requires glass microspheres or balloons filled with deuterium and tritium. The inner and outer walls of the spheres must possess a high degree of spherical symmetry as well as having both walls concentric. The number of spheres required to test laser fusion is of the order of 100/sec, but the current acceptance rate for spheres manufactured on earth is 1 in 10^{11} . There is some indication that the low-g environment will improve this situation.

Other comments were:

- The idea that space logistics is a key problem came up repeatedly.
- Fully automated systems for processing in space will not be feasible for at least 10 years and that man will definitely be required in space for some time to come. The processing of biologicals appears to be particularly attractive because biologicals are health-related.
- Successful processing in space will create jobs.
- Examples of various experiments already conducted include: sphere forming (on Skylab); radioactive tracer diffusion; vapor growth of crystals; drop tower tests (3.5/sec free fall); Spar rocket tests, and the various tests performed during Apollo-Soyuz mission.

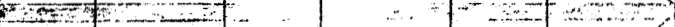
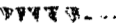
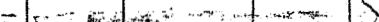
SPACE PROCESSING - WHERE WE ARE NOW

Mathias P. Siebel

Assistant to the Director, Space Sciences Laboratory
Marshall Space Flight Center, AL 35812

Dr. Siebel gave an idea of where the Shuttle program is now with emphasis on anticipated launches and materials processing in space. The chart below gives launches and activities with respect to the 1985-2000 year time frame (some earlier programs are also given for comparison).

SCHEMATIC TIME FRAME FOR SPACE PROCESSING ACTIVITIES

Description \ Time Period	65	70	80	85	90	95	2000
Drop Tower [3-4 sec]							
Apollo 14, 16, 17		14,16,17					
Ground Based Research							
Skylab		73-4					
ASTP							
Rocket (SPAR)							
Shuttle							
Spacelab							
Satellites (pwr mod)							
Satellites (ET)							

It has been very difficult to characterize the various parts of the space processing program in a rational fashion. Attempts are made to divide it up by process, material, apparatus, and phenomenon. In the case of processing in space, it appears that one ends up with a matrix in which all is connected to all. A group of outside consultants to Marshall on Space Processing has organized themselves into the following committees:

- Glasses
- Biologicals (Separation)
- Semiconductors
- Metals and Alloys Solidification
- Fluid Mechanics (Phenomenological)

There are other possibilities for classifications; such as, by-product area, by-apparatus, etc. The generic terms mentioned above are not the most radical breakdown; e.g., an area like fluids contains sub-topics such as wetting, surfaces, convection currents, and structure. These subitems obviously cut across the major divisions mentioned above.

The following comments are made with reference to the above chart "Schematic Time Frame for Space Processing Activities."

- Apollo 14 had a furnace capable of a 230°F. Heat flow and convection as well as electrophoresis experiments were also performed.
- Electrophoresis experiments were flown again in Apollo 17.
- Heat flow and convections (successful experiment) were also flown in Apollo 17.
- Probably the most important experiments to date were flown in Skylab (1973-74).
- Skylab furnace reflow and two electrophoresis experiments were performed in ASTP (1975).
- Ground work is continuing.

The discussion then turned to vehicles themselves.

Shuttle: This will be the principal vehicle. OFT: first six flights are primarily Shuttle flight testing. Materials processing experiments will probably ride piggyback on flights 5 and 6 with a probable launch date in 1980. These processing experiments must not interfere with the primary mission.

Spacelab: The Spacelab will be provided by the European Space Agency with the first Spacelab flight carrying both U.S. and European experiments. ESA is very interested in space processing. There will be many space processing missions during the flights in and after 1981. The missions are currently seven days in duration with some thought being given to 30-day missions. The Germans are thinking about a free flying spacelab by the 1990's. We are also looking at a free flying manned or unmanned variation.

Satellite: The external tank, which is 160 ft. long and 27 ft. in diameter, will possibly be used to construct an orbiting satellite. Thought is being given to installing a bulkhead in the liquid oxygen tank.

Several points were then brought out in response to questions:

- The NASA funding picture appears reasonably flat in constant dollars. It does fluctuate as programs mature and are spun off.
- In time frame of our study (1985-2000) it is realistic to think in terms of something more than Spacelab.
- DOD and NASA planning phases were discussed. There phases are outlined in the Table below. NASA generally lumps the phases C and D together. NASA needs no specific

Congressional authorizations to initiate the A and B phases but in order to proceed to the C and D phases, new start authorization is required. Mission 3 of Spacelab has some phase A and B contracts and is transitioning to the C/D phases.

- The Shuttle is limited to LEO (low Earth orbits). Some Shuttle payloads will contain the means for boost to higher orbits. The Shuttle is designed for a minimum of 50 missions or 10 years of useful life.
- The Power Module is in the A stage with a task team having been formed to conduct the phase A study.

TABLE

Phase	Description
A	Feasibility studies are done with alternatives developed and critical points identified.
B	An alternative is selected; recommendations are made; and a Preliminary Design Review is generated and completed.
C	Build a proto-type demonstration; generate the Critical Design Review; the Design is 90% complete at this stage.
D	Production phase

SPACE SHUTTLE CAPABILITIES

A. Pete Leberte
Marshall Space Flight Center, AL 35812

For a fairly complete summary of Mr. Leberte's talk, see Reference No. 1 below.

The Shuttle is the present national Space Transportation System (STS). The spacecraft, called an orbiter, is about the size of a DC-9. FMOF - first manned orbital flight - is expected to occur about March 1979.

The Shuttle will provide

- Lower costs
- A reusable vehicle
- Rapid turn-around use time - perhaps every two weeks
- A multiple use spacecraft
- Space station capability of seven days (could be extended up to 30 days with additional life support).

Shuttle costs are based on 572 flights, with 100 missions for each orbiter (see attached chart for cost comparison). Each flight will lose a \$2 million (1971 dollars) external tank which is included in this cost estimate.

The first six orbital flights of the Shuttle are development/test flights, and the seventh is considered as the initial operational capability flight. NASA/Houston is in charge of mission planning. NASA/HQ is in charge of payload planning.

Rockwell International is building the first two orbitors in a \$2.9 billion program. The first five Shuttles are to be built for civilian and military use. In addition to the facilities being readied at Kennedy Space Center, Florida, some are being built at Vandenberg Air Force Base, California.

The first glide test of the Shuttle is expected to occur in late July 1977. (Editor's Note - Test was successful.)

References:

- (1) "Space Shuttle," America's Space Transportation System, U.S. Government Office 1977 - 740-049/144 Region No. 4.
- (2) "Space Shuttle - The New Baseline," M. S. Malkin (NASA - Office of Manned Space Flight, Washington, D. C.) Document A 74-17050, Astro & Aero, Vol. 12, Jan. 1974, pp. 62-78.

SPACELAB

Carmine E. DeSanctis
Assistant for Experiments/Payload Requirements
Marshall Space Flight Center, AL 35812

Spacelab is a versatile general purpose orbiting laboratory which will be a major element of NASA's Space Shuttle System. Its objective is to provide an economical laboratory and/or observatory where scientists and engineers can conduct scientific, application, and technology experiments in LEO.

The facility consists of two basic elements: (1) A pressurized module and (2) an unpressurized pallet. Flight configurations consist of:

- . Module only (two maximum)
- . Pallet only (five maximum)
- . Modules plus pallet

A total of eight different configurations are possible. The crew will consist of commander, pilot and a mission specialist plus from one to four payload specialists. The module will house equipment and provide work space for the payload specialist. Experiments can be mounted on the pallets at launch site or the pallets can be sent to a factory or university for experiment mounting.

Spacelab is being built by European Space Agency (ESA) consisting of Germany, Italy, France, United Kingdom, Belgium, Ireland, Sweden, Austria, Spain, Netherlands, Denmark, and Switzerland. ESA will be responsible for the design, development, testing, and for the delivery to NASA of:

- . One engineering model
- . One flight unit
- . Two sets of ground support equipment (GSE)

NASA is responsible for the overall planning and management, space hardware development, and operation of the facility. MSFC is the lead center. The first flight of Spacelab is scheduled for 1980.

Some energy limitations:

- . Cooling capacity - 8.5 kW
- . Power available - 7 kW from orbiter
 - Spacelab basic requirement - 4.1 kW
 - Available for other uses - 2.9 kW (7.4 kW peak)
- . Total energy available - 490 kWh

Operations mode:

- Level 4. the experiment equipment and the space hardware are assembled and debugged.
- Level 3. the experiment equipment and the space hardware are assembled with the primary module structure.

Level 1. the experiment equipment and space hardware are assembled in the space shuttle cargo bay.

Spacelab subsystems discussed included heat dissipation, view ports, film storage kit, remote manipulator, pallet configuration, subsystem igloo, pallet structure, payload mounting capability, electric power and energy, and cold plates (8 available).

Spacelab is discussed in considerable detail in the NASA publication:

Spacelab
Payload Accommodation Handbook
June 30, 1977, issue

SPACE PROCESSING - POTENTIAL PRODUCTS

Robert J. Naumann
Chief, Space Processing Division
Marshall Space Flight Center, AL 35812

Materials processing in space has two major advantages over Earth based processing:

- . Ultrahigh vacuum environment
- . Absence of undesirable gravity effects
 - allows containerless processing
 - avoids gravity-driven convection
 - avoids sedimentation

Absence of sedimentation allows the processing and mixing of otherwise immiscible materials which differ in density. The manufacture of high-technology batteries consisting of copper halides and aluminum oxide is possible.

Monodispersive latexes, e.g., emulsion with uniform-size particles (beads), were grown in space with no sedimentation. This makes it possible to design membranes and study human eyeballs. Monodispersive latexes, which may have cancer-curing applications, have an attractive market according to the president of Polyscience. Insulin also can be produced without sedimentation.

Absence of convection allows effective living cell separation by the continuous-flow (electrodynamic) or the electrostatic technique. Use of the electric energy field on Earth causes heating which in turn causes thermal-gradients and density-driven convection. Convection also interferes with growing silicon single crystals. Highly-doped silicon was made in both Skylab and Apollo-Soyuz Test Project (ASTP). Boron arsenide (BAs) also is thought to be best formed in zero g.

Containerless processing, electromagnetic or acoustic, is used when impurities cannot be tolerated, as in glass. Heterogeneous nucleation can be achieved with acoustic waves using an inert gas such as argon. Optical fibers and silicon ribbons can be made in space as well as uncontaminated tri-metal alloys, e.g., cadmium-mercury-tellurium (CdHgTe). These alloys sell for over \$100,000/mg. Enhanced diamond crystal production is also envisioned.

Materials processing in space is presently limited to high-priced materials.

A high-vacuum environment (10^{-17} to 10^{-15} torr) is available in space by (using the wake shield in LEO). A purification process to produce pure thorium (Th) or gallium arsenide (GaAs) or even tri-metal alloys such as gallium-arsenide and aluminum (GaAs-Al) could produce highly thermal resistant, efficient solar cells.

Companies manufacturing silicon solar cells now spend \$50 M/year for research and development. Single-crystal silicon solar cells made in space can result in highly efficient (20%), heat resistant (460°C) solar cell-solar collector arrangements.

SPACELAB PAYLOADS AND EQUIPMENT STUDIES

William R. Adams
Manager, SPA/SL Payloads
Marshall Space Flight Center, AL 35812

Space Processing or Materials Processing in Space is oriented around the properties of space, i.e., high vacuum and low gravity. These properties allow convectionless and containerless processes to occur. Some of the processes mentioned were:

- . Large single crystals
- . Alloys
- . Bio-processing

Plans for research were begun in 1972 with automation studies begun in 1974. These studies were to determine scientific interests and needs, define hardware concepts, and recommend a management approach. In August 1976 MSFC recommended eight new modular payload systems. At \$100 M they cost too much.

In October 1976 OA requested MSFC to proceed with a materials processing program using Shuttle. Biomedical and electronics materials were to be top research priorities.

A Phase B study was performed during the period 1 December 1976 to 31 March 1977 by GE, MDAC and TRW. Technical interchange meetings were held and copies of this report were distributed.

GE was responsible for experiment requirements, function flow, equipment schematics, and equipment specifications.

Final Reports are available. Topics and MSFC persons responsible are:

Continuous Flow Electrophoresis	Dr. R. S. Snyder
ASTP Static Column Electrophoresis	
Multipurpose Fluid Phenomena	Dr. R. L. Kroes
Multipurpose Furnace	Dr. M. C. Davidson
Float Zone Refining/Crystal Growth Furnace	
SPAR Electromagnetic Containerless Process	Mr. L. H. Berge
SPAR Acoustic Containerless Process	

Mission Planning. Phase 1 of the Project Plan contains two flight opportunities. Spacelab 3 mission will contain a biomedical apparatus and fluid research system. A Satellite Deployment Mission #(TBD) will also contain a solidification system to take advantage of the additional spacelab housekeeping power (total 5 kW). The equipment is designed for multiple flights.

Design and Development Procedures for Shuttle/Spacelab Project includes:

- . Ground Based Equipment Lab
- . Payload Specialist Training Sequence
- . Spacelab Module Payload Power Profile

Summary. SPA/SL payloads will be established and operated with science priorities within dollar and schedule limits.

Planning activities meet 80% of presently identified scientific needs.

Follow on starts will be made to accommodate additional research projects.

There will be P.I. participation.

NASA has given high priority to the following program aspects:

- . Provide access to space
- . Design, develop, integrate and operate facility
- . Fluid research

Spacelab is too small. Twice the power and heat rejection is required than is presently available to manufacture silicon ribbon. Two phases are possible:

- (1) Do pure research now.
- (2) If Spacelab can be designed for adequate power and heat rejection, an entire lab might be dedicated to space processing, e.g., culture cells in space.

SPACE INDUSTRIALIZATION -- OBJECTIVES AND OVERVIEW

Claude C. Priest
Senior Project Engineer, Advanced Systems Group
Marshall Space Flight Center, AL 35812

with

Chuck Gould
Project Manager, Advanced Systems
Rockwell International
Downey, CA 90241

and

Gerald Driggers
Science Applications, Inc.
Huntsville, AL 35801

NASA began long-range planning several years ago to include program planning for:

- Technology
- Applications
- Exploration
- Aeronautics
- Space Industrialization

Long-range planning includes a 25-year outlook and a 5-year plan.

Detailed planning presently includes activities proposed for the time period FY 78-FY82 with topics for detailed planning encompassing:

- On-going programs
- New starts
- Development plans

Two planning studies have recently been conducted under contract to NASA:

- Rockwell International - Aerospace Viewpoint
- Science Applications, Inc. (SAI) - Research Viewpoint

Mr. Priest introduced Mr. Chuck Gould, Project Manager for Advanced Systems for Rockwell, who led a detailed discussion of the Rockwell report just completed. The general topic "Space Industrialization" included such detailed topics as:

- Space processing
- Public and personal service
- Satellite power systems

The discussion began with a general review of deteriorating earth resources, global problems, and the consequences of continuing the present environmental abuses. The discussion led through various alternatives to include some advantages of space industries and the most likely applications in the near future. The topics are so numerous and varied that they are not listed in this summary -- the interested reader should refer to the Rockwell summary or the report, which was included in the mailing list to all participants.

Mr. Priest also introduced Mr. Gerald Driggers, Aeronautical Engineer for SAI, who led a detailed discussion covering the SASAI Report just completed. The general title "Space Industrialization" was reduced to 3 questions:

- What is space industrialization?
- Why industrialize space?
- How could space be industrialized?

Mr. Driggers developed fully the conclusions included in the SASAI Report, to include a sample program analysis through the year 2010. The conclusions were related back to current NASA planning and to the possible directions the present planning could go.

Again, as with the Rockwell Report, the topics are so numerous, the reader is referred to the SAI Summary of their report which was included in the mailing list to all participants.

SPACELAB - AN OVERVIEW

Heinz Stoewer
European Space Agency
Noordwijk, Holland

The seminar consisted of a brief opening statement followed by a question and answer period.

STATEMENT

The first priority is to complete Spacelab on schedule. Further incremental development is planned over the next 5 to 10 years. This includes the problems associated with the increase in mission duration from 7 days to possibly 30 days, such as power, heat rejection, sub-system reliability, and data handling systems. Subsequent development includes making Spacelab independent of the shuttle, which requires the addition of the NASA power module and of one or more manned modules.

QUESTIONS - AND - ANSWERS

- Q. Is the funding of the German space processing effort public or private?
- A. Presently, most public. It is hoped that after Spacelab has proven itself, that the funding will be mostly private.
- Q. What are the main Spacelab problems?
- A. Time and money, but we have done better than expected.
- Q. What are the problems and costs associated with making the Spacelab independent of the shuttle?
- A. I estimate that getting the Spacelab out of the Shuttle may be roughly one half of the present Spacelab R&D cost. It could be less depending on the technical solution chosen.
- Q. What does the ESA look for in terms of return on investment on the Spacelab?
- A. I don't know. Part of the motivation for building the Spacelab is political, which includes the desire to participate with the United States in a manned space effort, and to learn the management techniques associated with such a diverse activity.
- Q. Why does Germany contribute 53% to the costs of Spacelab?
- A. Spacelab is a special program and as such is funded not on a basis of percentage of the GNP - as the normal programs - but according to the interests of the respective nations. Three special projects were funded at the same time. France and Britain contributed mainly to the other two, while Germany concentrated on Spacelab.

Q. What is the outlook for future ESA budgets for the Spacelab?

A. Probably no one knows at this time.

Q. How does ESA arrange for payload payment on the Spacelab?

A. The first flight will be shared equally by the USA and ESA. Subsequent flights have not been divided.

Q. What is the demand for space on Spacelab?

A. Moderate. It should improve with time.

Q. Do you plan Spacelab missions in higher orbits?

A. There is no present need for higher orbits that will justify the costs.

Q. What is the lifetime of the Spacelab hardware?

A. 50 missions or more.

Q. How many Spacelabs will you build?

A. At the maximum 5. We anticipate a total of 275 missions.

Q. Will all Spacelab missions be reserved for European companies?

A. No.

Q. Would ESA cooperate with the Soviet Union?

A. We will cooperate with all nations as long as the effort is scientific and not military.

Q. How would you make an international space station?

A. It depends on your assumptions.

Q. Do European countries grant fiscal benefits to companies to use the Spacelab?

A. No.

Q. Does ESA have economic studies on space processing.

A. Yes, many, but I cannot quote any.

Q. Does ESA study future space stations?

A. We have just now started.

Q. Are NASA management techniques helpful to ESA?

A. Very.

Q. Does ESA plan shuttle launch sites in Europe or the production of shuttles?

A. No, on both counts.

Q. Does ESA have an interest in heavy launch vehicles?

A. Who knows at this time?

SPACE STATION STUDIES - AN OVERVIEW

William G. Huber
Manager, Space Station Task Team
Marshall Space Flight Center, AL 35812

The reader is directed to the paper "Space Station Overview (25 Power Module)" for detailed information about Mr. Huber's talk.

Mr. Huber's talk was one of three presentations on Space Station studies:

- William Huber - An Overview and Detailed Discussion of of the Power Module (PM)
- Richard Kline - The Development of the PM into a Space Station
- Gary Geschwind -Space Processing and Manufacturing

The main goal of developing a space station is to put human beings in orbit for extended periods. The space station is a tool with which it is useful to do something; in particular, industrialization activities in a space environment.

Definitions:

- Space Station - A structure with the capability of allowing humans to orbit indefinitely.
- Space Construction Base - A special type of space station that can be used as a base to build large structures in orbit.
- Space Platform - Normally for scientific use; it may not be permanently inhabited.
- Shuttle - A tended station; personnel return with the Shuttle.
- 25 kW Power Module - Initially planned power module (PM).
- Large Power Module - Advanced power module capable of generating hundreds of kilowatts (250 or 500 kW).

SPACE STATION CONCEPTS

Richard L. Kline
Grumman Aerospace Corporation
Bethpage, NY 11714

Mr. Kline's presentation consisted of four inter-related components:

- ° Missions and Requirements
- ° Scenario and Programmatics
- ° Concept Evolution
- ° Conclusions and Recommendations

Missions and Requirements. Several missions were selected from a wide host of candidates which were initially considered by GAC. The specific missions which were selected and presented in some detail included: Technology development for Solar Power Satellites (SPS), space manufacturing, Public Service Platforms (PSP) and beneficial scientific missions (solar-terrestrial observations, life sciences and others).

The SPS in GEO would capture the solar energy, convert it on-board to microwave and beam it down to Earth. It would be received by an earth-based microwave receiver and converted into electrical energy. It is anticipated that the SPS would be assembled at LEO, then boosted to GEO, as opposed to assembly at GEO following direct launch to GEO. One key step in SPS development was the Solar Power Development Article (SPDA) which would broadcast its energy to another satellite for "end-to-end" verification demonstration and technology development of system components.

The Public Service Platform (PSP) offers/requires the unique reversal of the current transmission/reception concepts; the PSP places very large antenna and support equipment in orbit, which now makes possible very small senders/receivers on the ground.

With respect to space manufacturing, Mr. Kline's study indicated that it is necessary to concentrate on process, rather than on product. The study also investigated and recommends the development of dedicated modules; i.e., a separate module dedicated to a specific mission (biological, manufacturing, etc.).

Beneficial Scientific Missions (BSM) could include the Solar Terrestrial Observatory (STO).

Scenario and Programmatic. Several program cost options were considered which were functions of time/phasing of the development, precise evolutionary path description chosen/followed, lead time afforded therefrom and the progression of controls development (tended, manned, etc.). Each cost comparison element included DDT&E, production and operations costs. Peak annual funding was considered. Space stations evolutionary considerations included the events-projects-hardware evolution, together with the functional increase in power requirements in unison with hardware/station growth.

Concept Evolution. The size of the construction system depends on exactly what function you want to perform. The integration of the external tank was considered an attractive space station/construction workbench feature due to a variety of advantages. These included: Immediately available in orbit, high strength/stiffness spine, large area for modular attachments, high inertial, large internal volume and low payload penalty.

A "beam-builder concept" was presented and discussed which also included a brief film showing conventional terrestrial, cold-rolling beam fabrication processes. In space it would be entirely possible to manufacture very long structural members with a minimum number of joints -- thereby alleviating many of the structural problems (extra time and costs to assemble, extra cross-members required, etc.).

Conclusions and Recommendations. Recommendations included the technology development of space power stations for use on Earth along with the design, development and construction of a space construction base system.

Conclusions focused on three major areas:

1. The Shuttle program ushers in an entirely new era affording routine access to space and space operations,
2. Space stations can provide permanent facilities for a variety of functions, including space industrialization, and
3. The new era of space utilization is limited only by man's ingenuity to be able to imagine, recognize and define the opportunities before him.

RESULTS OF SPACE PROCESSING

Gary Geschwind
Grumman Aerospace Corporation
Bethpage, NY 11714

Potential products resulting from space manufacturing activities can be classified either as organic or inorganic. Dr. Geschwind identified three products being studied:

- Urokinase
- High coercive strength permanent magnets
- Silicon ribbon

The choice of these products were largely dictated by past NASA successes.

Urokinase was successfully cultured from kidney cells separated on ASTP in the MA-011 experiments. The use of urokinase as a potential therapeutic for thromboembolic diseases provides an example of the benefits which the nation might reap from demonstrated success of biological processing in low gravity.

Low-g experiments on electrophoresis and tissue culturing have been carried out both here and in the USSR since 1961. Tissue culturing was identified as a very attractive candidate process which might benefit from space manufacturing, but the results from low-g flights to date have been ambiguous.

Three models have been considered for determining the upper and lower bounds on the profitability of manufacturing urokinase in space. The study shows that the profitability of urokinase hinges on the availability of recycled, purified water from the Space Construction Base (SCB) or from the Shuttle. Additional profit can be generated by having water recycling (from human waste, recovered from the air, etc.) on board the SCB or from fuel cells on the STS. The STS would have to dump the excess water overboard to reduce its weight prior to reentry.

The pilot plant manufacturing of urokinase is planned for 1985 with commercial production two years later.

A complete analysis on the benefits, market analysis, hardware requirements, module conceptual design, and research and development plan for urokinase and high coercive strength permanent magnets was performed.

A significant improvement in the magnetic properties was demonstrated in MnBi/Bi directionally solidified eutectics in the MA-070 experiment on ASTP. Directional solidification was selected as the process because of the large number of potential products which might result from successful space experiments - commercial cobalt/rare earth (CORE) permanent magnets, higher temperature turbine blades, optical wave guides, and high critical-temperature superconductors.

Coercive strength and energy product $(BH)_{\max}$ are the two important properties of permanent magnets. The energy product is the work that is stored in the field of a permanent magnet. If improvements in energy product by space manufacturing equivalent to what was achieved on MnBi/Bi in the MA-070 experiment on ASTP could be accomplished, a significant market would exist for space manufactured CoRE materials.

Another advantage of space-processed magnets will be their stability, a result of the oxygen-free environment in which they are processed. This property is of particular importance in their application to inertial guidance units for aircraft and ship navigation. Motors using space-processed rare earth magnets are more efficient, smaller in size and weight, and more resistant to demagnetization.

A number of crystal growth experiments on ASTP and Skylab have shown great promise. An existing NASA funded study for silicon ribbon manufacturing was used to develop the SCB requirements.

Several simple models have been developed for the comparison of the operational costs of carrying out manufacturing on Spacelab with the SCB. The main purpose is to see if large differences exist. The study shows that both Spacelab and SCB can play a role in the sequence of events leading to commercial manufacturing, but SCB is needed for profitable manufacturing.

One of the important achievements of the study was the uncovering of those critical issues which might limit the success of space manufacturing on SCB. For detailed description of the critical issues, study conclusions, and recommendations, please refer to the handout: Space Manufacturing Concepts by Dr. Gary Geschwind, Grumman Aerospace Corporation.

Once again, the audience was reminded that only strong NASA participation (funding) through the prototype stage will make manufacturing in space successful.

HEAVY LIFT LAUNCH VEHICLES

Milton A. Page
Marshall Space Flight Center, AL 35812

and

Daniel L. Gregory
Boeing Aerospace Company
Seattle, Wash. 98124

Mr. Page outlined the "Shuttle Growth Study" by Rockwell International, the "STS-Designed HLLV Study" by the Boeing Company, and the Shuttle Derivative Vehicles Study by Boeing. Some pertinent points emphasized were the need to:

- . Define a series of STS-derived heavy lift launch vehicles taking into account configuration, performance, cost, and programmatic requirements.
- . Optimize HLLV design for a spectrum of payload weights and launch activity levels.
- . Identify building block families.
- . Conduct a comparative evaluation and select the most attractive configurations.
- . Have operational vehicles in the time period 1983 - 1990.
- . Achieve low cost by recovery and reuse of the vehicles.

The typical mission envisions a two-stage vehicle with sea recovery of the first stage via parachute. After the payload is deployed, the capsule returns to launch site, also via parachute.

Mr. Gregory next gave the details of the "STS-Devised Heavy Lift Launch Vehicles Study." The study conclusions were:

- . The Shuttle derived HLLV is a cost effective option for space station and manned scientific programs and has 2 to 3 times the Shuttle payload with smaller cost per flight.
- . The class 4 HLLV meets \$20/lb required for solar power satellite.
- . The key to low cost is recovery and reuse.

The key elements of the HLLV Operational Scenario are:

- . 5 day work week, three shift - three launchers per day
- . 48 hour minimum turn around, vehicles cycle every 5th day
- . Vehicle processing separated from payload processing
- . Minimum time on MLP
- . Ship transport not sensitive to LV weight
- . Minimum number of launch pads
- . Recovery transit time utilized in maintenance cycle
- . Utilizes existing KSC support facilities
- . Incorporates maintenance techniques of STS and airlines

In summary:

- . Review of non-space transportation operational features indicates:
 - Profit oriented
 - Maintenance considerations are an integral part of development cycle
 - Maintenance is a time evolving process
 - Engines are a major maintenance cost element ($\approx 50\%$)
- . HLLV operational scenario includes
 - Desirable features of the non-space transportation systems and STS
 - Maximum utilization of facilities and equipment at KSC
 - Operational flexibility
- . HLLV operating costs
 - $\approx$ \$7M per launch appears achievable
 - Major cost elements include expendable shroud (25%), refurbishment/spares (24%), propellant (17%), and ground OPS/SYS (10%)

. Special studies

- Alternate launch sites -- offer potential performance (17% to 19% fewer flights) and environmental advantages
- Sea vs. land recovers -- driven by a number of inter-related factors

LARGE SPACE STRUCTURES

Hugh J. Dudley
Chief, Special Projects, Payload Studies Office

with

Erich Engler and
Dwight Johnston
Marshall Space Flight Center, AL 35812

Mr. Dudley organized the session in three modules:

- A. Program Overview - Mr. Dudley
- B. Beam Machine Design - Mr. Erich Engler
- C. Space Spider - Mr. Dwight Johnston

A. PROGRAM OVERVIEW

- Large structures fall in three categories:
 - Dishes -- Communication, earth observation
 - Booms -- Positioning, communication, construction
 - Planar Surfaces -- Platforms, solar arrays, illuminators
- Background in structures at MSFC:
 - Pegasus in early 60's
 - Night illuminators in mid 60's
 - Communication/navigation antennas in mid 60's
 - Satellite solar power, 72 - 75
 - Public service platform in 76
- Various supporting technologies are also available at MSFC.
- The objective of the large structure effort at MSFC is to plan and develop the capability to package, transport, fabricate, erect, and operate large structures in space using the Shuttle.
- The large structure effort is in the following areas:
 - Beam fabrication (beam building machines)
 - Simulation
 - Space spider (machine to generate large surfaces analagous to a spider web)

- Studies/analysis leading to a capability demonstration in the 1982 - 1983 time period
- Deployable antennas
- The capability demonstration is planned in two phases: The first being to demonstrate the operation of the beam machine on Shuttle in 1982; the second would be to assemble some useful structure in 1983. There are two beam machine activities -- one using metal, probably aluminum, the other using composite materials. Depending on additional study, either or both of these machines may be used.
- The simulation program will involve building structures in the Neutral Bouyancy Simulator, the use of the T-27 docking simulator and the Mobility Lab Simulator to optimize the structure and assembly operations.
- Research and technology support for the large structure effort will come through a program centered at Langley called Advanced Technology for Large-Area Space Structures (ATLASS) with an \$80 to \$100 million budget over the next five years.
- Comments were made about deploying devices at LEO.
- Systems work is being done on teleoperator.

B. BEAM MACHINE DESIGN

The large structures group feels it is necessary to have a machine which will generate open truss triangular beams in LEO. The machine would be free-flown and then raw material supplied to the machine by subsequent Shuttle flights. The best metal seems to be aluminum. Fiber composite materials (and, thus, a composite material beam machine) are being considered; e.g., graphite in matrix of epoxy, thermoplastic or polysulphon. The advantage being sought is thermal stability. The materials must withstand about 9 g's on the ascent flight. MSFC is now working on ground demonstration machine. Spot welding will be the method for fastening with various types of end fittings for the beams being considered.

C. SPACE SPIDER

The structure construction concept devised by Dwight Johnston and others is patterned after the construction technique of a spider making its web. The idea was stimulated by thinking about how structures would be connected to form a 1200 acre solar power satellite field. Although teleoperator manipulative type systems are expected to be utilized

in the assembly of truss-type space structures, the space spider, which is another type teleoperator system is thought to be considerably more efficient. Mr. Johnston is responsible for MSFC's teleoperator development activities.

A 15-foot dia. roll of 0.015" aluminum rolled on a 2-foot dia. core could have 102,000 lineal feet of material and would form a 1,432-foot diameter circular structure with trusses 15.9 feet long. Covered with photovoltaic cells, this would yield 15 MW. Due to weight limitations, only a 9-foot diameter roll could be carried aboard the Shuttle, but this is sufficient to build a structure which when covered with photovoltaic cell would generate 5 million watts.

Laser interferometers built into the spider's control system would provide a means for the spider to continually control the shape of the structure it is building.

HISTORICAL AND FUTURE ASPECTS OF SPACE FLIGHT

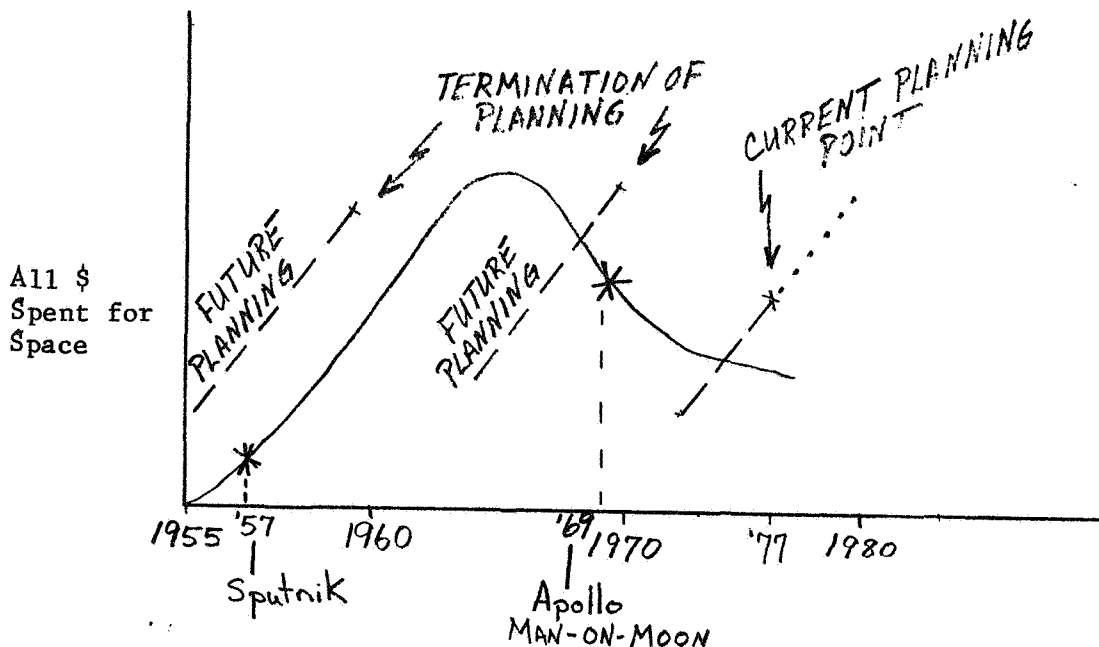
Robert F. Freitag
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Mr. Freitag informally addressed the group stating his perception of the space program in the 30 years he has been involved with it and his projections as to future developments.

Introduction. Historically, there have been three major decisions which have substantially affected the U.S. space program. They were:

- . 1955 - President Eisenhower's decision that the U.S. would go into space - especially for research purposes.
- . 1961 - President Kennedy's decision to use space; the most common examples being: man on the moon; military use of space; comsat; weather bureau; initial European involvement.
- . 1969 - Decision to phase out the use of expendable launch vehicles and begin development of re-usable spacecraft. This decision was made primarily on the economics of transportation rather than technical capability.

These three decision periods affected funding levels and the activity of future planning as shown graphically below:



The concept of inverse complexity will pervade future space development in the form of a few, very large, complex Earth satellites with many, small devices on Earth. A large multichannel antenna in space with wrist receiver-transmitters is an example of inverse complexity. This is inverse to historical scenarios in the use of space.

Missile Development. During WWII the Germans fired ~ 7000 rockets. Approximately 1/2 failed in mission due to unreliability of fuels, materials, guidance, etc.

Modern ballistic missiles of high reliability came to fruition due to a number of technical and organizational developments all maturing simultaneously. Some of the technical developments included: digital computers, H-Bomb technology, guidance system technology, rockets, fuels, transistors, new structural materials and new ceramics. The advent of systems engineering and other managerial techniques contributed significantly to man's ability to organize an effective attack on the solution to big problems.

Future Scenarios. Another technological revolution is upon us. The result of this revolution will be to move out of the space R&D phase and into the space industrialization phase. The new revolution is being powered by developments in:

- New materials
- Microprocessors
- Better rockets
- Space Shuttle (routine travel to and from space)
- New management and mode of operations

The four major systems derived from the use of space are:

- Large Antennas - for electronic communication
- Observation - weather/geological/etc.
- Space Processing - materials/biologicals/etc.
- Reference Platform - stepping stone to deep missions/lunar missions/etc.

The international use of space will evolve in several ways.

- Many countries will leapfrog developmental costs of past technology and use space directly (e.g., communication satellites).
- There will be global communications at low cost.
- There will be continued opportunities for countries to cooperate in space ventures.

The U.S. should continue to take a leadership role in future space development. We should continue to be free and open in our sharing of information with other countries for the following reasons:

- We will create markets for our products
- We are just at the beginning of an opening of a space era that can produce increased international understanding/cooperation.

Conclusion. The final part of Mr. Freitag's discussion was a question and answer session. The questions and answers are summarized below:

- Q. How can NASA create a groundswell of public opinion in order to get the public strongly behind the space program?
- A. In several years we will get "shuttle shock" - an awareness by the public of the potential of space once Shuttle is flown routinely.
- Q. Will the NASA funding continue at ~ 1% of the U.S. budget?
- A. Yes. Until "shuttle shock" or some other major eureka development is found as a result of space processing/development.
- Q. Is the idea of space industrialization being used as a coverup for space militarization?
- A. No. The intent is to use space as a peaceful tool similar to use of a surgeon's knife as a tool rather than a weapon.
- Q. Is there a governmental agency that tells the public/institutions/etc. what has been discovered/developed in space?
- A. Yes. The Technology Utilization Office, which is part of every NASA center and which was authorized in the original space act, is responsible for this.
- Q. How can NASA get more corporate funding and industry involvement in space processing?
- A. NASA personnel haven't been as aggressive in pushing this idea as is possible. Also, we need to reformulate the roles between industry and government so that they are not in such adversary roles to each other; the Germans seem to be far ahead of us in this concept and practice.
- Q. Can NASA get more public relations money?
- A. They try, but Congress controls the purse strings and is currently tightening rather than loosening them. Also by law, NASA cannot force companies who receive contracts to advertise the space program.

Q. Will there be a strong cabinet level "science" agency in the new Administration?

A. No. Science is spread through every department/agency.

Q. Has the U.S. cut back too far in its overall R&D?

A. We have cut back from past levels but we are still an order of magnitude above all other countries combined.

Q. How do you view Dr. G. O'Neill's space colonization scenario?

A. NASA is modestly supporting O'Neill's work and expects in several years to commit several million toward Ph.D. type grants to study aspects of the problem. Space colonization may be possible given the new technological revolution.

APPLICATIONS OF SPACE FLIGHT IN MATERIALS SCIENCE AND TECHNOLOGY - NASA/
NBS CONFERENCE AND NAS/NAE/NRC STUDY

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Dr. Wachtman clearly stated his personal point of view that as of today he sees no profitable application of space manufacturing. He does foresee some utility for space conducted experimentation in the area of Inorganic Materials to advance our knowledge and provide a possible earth-based benefit. Dr. Wachtman outlined the ongoing work of a National Academy of Science/National Academy of Engineering/National Research Council (NAS/NAE/NRC) committee on the Scientific and Technological Aspects of Processing Materials in Space (STAMPS) and listed inorganic materials problems that have space research potential.

The STAMPS committee is composed of twelve scientists from fields related to space processing. Eight from the academic community, three from industry and one from government (Dr. Wachtman). The committee was funded by NASA in November 1976 for about a one-year period. Five 2-day meetings have been held by the committee and a final report will be drafted during the period July 26 - August 3.

Dr. Wachtman discussed in detail several materials problems for which space research might be useful. In this discussion he made clear his personal opinion that the only significant advantage to space processing is micro-g. He discounted the use of vacuum properties behind the wake shield as being obtainable on earth and the use of space radiation, notably solar, as not being unique. The following observations towards space processing were made:

- o Commercial space processing seems economically doubtful.
- o The development of prototype materials in space could be useful.
- o The preparation of materials in space for earth research could be important.
- o The measurement of material properties and behavior in space could be pertinent to better understanding of earth-based processes.

The following areas were reviewed:

- o Containerless processing on earth. Several limitations exist to each of the three current forms of earth-based levitation: electromagnetic, acoustic and aerodynamic. Of particular concern is the limited size of a liquid drop; e.g., 0.26 cm for water in air. The micro-g conditions of the free fall orbit reduce the problem of large melt levitation required for containerless processing.

- Crystallization vs. glass forming. Space processing offers the potential for homogeneous nucleation required to form oxide glass not yet produced on earth. These glasses have potential application in high-energy laser technology in areas such as laser fusion. Because such glasses are not currently available, their market demand can only be speculated.
- Bubble removal (fining) in glass. All glass manufacture is concerned with the removal of gas bubbles from the final product. Currently, fining is enhanced by a fining agent such as As_2O_3 which leads to air quality problems. The exact role of the fining agent is not fully understood. Further knowledge may be obtainable from space-based research. Another factor in bubble removal in glass is the g-driven Stokes rise. That phenomenon would not be present to aid glass making in space.
- Marangoni effect-bubble motion. In the micro-g environment of space orbit, Stokes rise will not be present to remove gas bubbles in glass. The dominant factor may be the gradient-driven Marangoni convection effect. This theory requires validation in a micro-g environment.
- Purification by vaporization. Such purification of materials would capitalize on the vacuum properties of space. This purification requires a lower relative vapor pressure for the impurity than the end product. Such vaporization can require extended processing times (10^3 to 10^6 seconds). Purification of large spheres will require stirring to refresh the surface with impurities.
- Containerless phase equilibria and thermodynamics. This is an open area for micro-g research with potential application to several areas.
- Crystal growing from melt and vapor. Micro-g will eliminate convection gradients. Research is needed to engineer the process of crystal forming.
- Others: flame chemistry, phase transformation and composites. All are potentially attractive research areas. Increased knowledge of flame chemistry might increase combustion efficiency and improve flame resistant materials.

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SPACE PROCESSING - B.U.S. STUDY, G.E.

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Mr. Bloom gave a lecture on the G.E. B.U.S. (Beneficial Uses of Space) study which involved three phases. The study in essence was to identify products, processes or services that would be best developed or produced in the unique environment offered by future spacecraft. A methodology was developed to gain and maintain interest and participation of non-aerospace organizations in this respect.

This involved dialogue with individuals and small teams to cross-fertilize ideas between space and non-aerospace experts. This was found to be an excellent way of acquiring ideas for products, processes, and services to be developed or produced via space efforts.

The method gained participation of 80 organizations represented by 403 key individuals. Of the 120 ideas derived in those dialogues, slightly over 100 were technically applicable and of sufficient interest to the key individuals to encourage further consideration and dialogue. From these, the data on 12 ideas were developed through critical evaluation. These 12 ideas then received further consideration in the BUS study (see Table 1).

The study objectives were:

- ° Identify specific organizations who were to be potential users who would contribute to development of products from the knowledge obtained in space.
- ° Identify the specific capabilities and knowledge obtainable in space that can be used to solve or identify development or production problems.
- ° Establish support from the specific users for programs to solve the various problems that have been identified.
- ° Review and assess possible benefits and impacts as a result of these solutions.

Mr. Bloom further explained that the initial studies were not isolated independent studies but instead were supportive efforts with NASA. The culmination of the data from the 1960's and space application studies from the 1970's were instrumental in the contributions to this study.

Following guidelines obtained from NASA, the Space Shuttle was considered the key to future applications. Frequency, reusability, and economy of Shuttle transportation were stressed to enlighten the business population as to the reality of Shuttle operations and to overcome skeptical attitudes.

Table 1

IDEA NO.		ISSUES, NEEDS, AND PROBLEM AREAS	REQUIRED KNOWLEDGE / CAPABILITIES
1	IMPRINTING CIRCUITRY ON CRYSTAL WAFERS FOR SURFACE ACOUSTIC WAVE ELECTRONICS	ELIMINATION OF VIBRATION FROM IMPRINTING SYSTEM	DECOUPLED PLATFORM FOR MOUNTING IMPRINTING SYSTEM (e.g., ELECTRON BEAM GUN) WHICH ELIMINATES LOW FREQUENCY VIBRATIONS, ACOUSTIC COUPLING.
3	PARTICLE MANIPULATION BY SMALL FORCES	ELIMINATION OF GRAVITY MASKING EFFECT	FACILITY WHICH ELIMINATES OR COUNTERBALANCES GRAVITY FORCE SO AS TO ENABLE A VARIETY OF MICRO-FORCE INDUCERS (e.g., LIGHT, HEAT, SOUND, RF, ETC.) TO ACCELERATE PARTICLES IN VARIOUS MEDIA.
5	VIBRATION TESTING OF SMALL MOTORS	IMPROVEMENT OF PRESENT 4 CPS LIMIT, ISOLATION FROM SONIC AND MAGNETIC FIELDS	DECOUPLED PLATFORM FOR MOUNTING PROTOTYPE MOTORS AND VIBRATION-MEASURING INSTRUMENTATION (e.g., LASER HOLOGRAPH) WHICH ELIMINATES SEISMIC VIBRATIONS AND ACOUSTIC COUPLING.
6	SINGLE CRYSTAL AND EUTECTIC HIGH TEMPERATURE TURBINE BUCKETS	CERTAIN SUPERALLOYS NOT AMENABLE TO CASTING; PRESENT CRYSTALS SMALL AND CONTAIN DISLOCATIONS; EUTECTICS CONTAIN DISLOCATION, ETC.	FACILITY TO MELT SUPERALLOYS, REFRACTORY METALS, EUTECTICS WITHOUT CRUCIBLE; GROW LARGE CRYSTALS ALONG SPECIFIC PLANES, WITHOUT INTERNAL STRAINS, ANOMALIES CAUSED BY CONVECTION, PRODUCE EUTECTICS WITHOUT DEFORMATIONS CAUSED BY CONVECTION; PROVIDE SUPERCOOLING OF SIZEABLE SPECIMENS AFTER CRUCIBLES MELT
30	HIGH PURITY TUNGSTEN X-RAY TARGETS	CONTAMINATION OF MELT BY CRUCIBLE	FACILITY TO MELT TUNGSTEN WITHOUT CRUCIBLE, PROVIDE SUPERCOOLING OF SIZEABLE AMOUNT AFTER CRUCIBLES MELT
42	PRECISE SEPARATION OF RADIOISOTOPES	HIGH SPECIFICITY SEPARATION TECHNIQUE	FACILITY WHICH ELIMINATES BUOYANCY, PRECIPITATION, CONVECTION FORCES; ALLOWS SMALL FORCES TO ACCELERATE ISOTOPE PARTICLES AT RATES RELATED TO SMALL DIFFERENCES BETWEEN ISOTOPES.
46	SILICON CRYSTAL GROWTH	CONVECTION DURING CRYSTAL GROWTH	CRYSTAL-GROWING FACILITY WHICH DECREASES CONVECTIVE FORCES IN MELT TO MINIMIZE NON-UNIFORMITIES IN DOPANT DISTRIBUTION, THUS INCREASING UNIFORMITY OF CRYSTAL ELECTRICAL PROPERTIES; ALSO TO GROW LARGER CRYSTALS.
59	EPITAXIAL GROWTH OF MAGNETIC BUBBLE MEMORY CRYSTALS	CONVECTION, LOSS OF SUPER-SATURATION	EPITAXIAL CRYSTAL-GROWTH FACILITY TO ELIMINATE CONVECTIVE CURRENTS THAT CAUSE THE NON-UNIFORMITIES IN TEMPERATURE AND SATURATION LEADING TO NON-UNIFORMITIES IN FILM THICKNESS AND MAGNETIC PROPERTIES; ALSO TO GROW LARGER AREA CRYSTALS.
60	AMORPHOUS GLASSES AND REFRACTORIES	CRYSTALLIZATION DUE TO INCLUSIONS, CONVECTION	FACILITY TO MELT AND SUPERCOOL GLASSES AND CERTAIN OXIDES WITHOUT DEVITRIFICATION CAUSED BY CRUCIBLE SURFACES, CONVECTIVE CURRENTS, INCLUSIONS.
84	BASIC HEAT TRANSFER DATA	CONVECTION DURING MEASUREMENTS	DATA ON THERMAL CONDUCTIVITY OF LIQUIDS (ESPECIALLY OILS) IN ABSENCE OF CONVECTION
89	SEPARATION OF ISOENZYMES	DENATURATION OF ISOENZYMES BY SEPARATION UNDER G LOADING	FACILITY TO SEPARATE ISOENZYMES WITH VERY WEAK FORCES SO AS TO AVOID DENATURATION WHICH OCCURS WHEN SEPARATION REQUIRES LARGER FORCES (e.g., WHEN PERFORMED IN ONE G)
96	UTILIZATION OF BIORHYTHMS	TERRESTRIAL INFLUENCES	DATA ON PHYSICAL AND BEHAVIORAL WELL BEING OF SUBJECTS WHEN POTENTIAL INFLUENCES (e.g., LUNAR, MAGNETIC, GRAVITY, ETC.) ON BIORHYTHMS ARE VARIED. FOR USE IN POSSIBLE MODIFICATION OF DIAGNOSIS, THERAPY, WORK CYCLES.

Required Knowledge/Capabilities, B.U.S. Study (Phase I) Final Report, Vol. I, Executive Summary, Contract NAS8-28179, Dec. 1972, pg. 3

The following processes were among those that generated interest among the users during the first phase of the BUS study:

- Electrophoretic separation
- Levitation melting
- Crystal growth

A problem that occurred during the first phase of the B.U.S. Study was that the lack of user knowledge of the Space Shuttle, automated spacecraft, and their payloads, made written commitments for company-funded development impossible.

Some conclusions on the methodology used in the first phase of the study were:

- ° It was agreed that, if five or six good ideas were found, the study would be a success. The figure was almost doubled.
- ° For gaining and maintaining user interest, it was learned that more complete planning and benefits analyses should be performed. These became the subjects of Phase II and Phase III efforts.
- ° Large commitments to, or from, users require more exchange of information. Longer associations with users is necessary to increase their confidence in space activities.

The Phase I study results indicated that:

- ° Zero-g remains the most promising space property, and is required for levitation melting, crystal growth, separation of particles, and measurements.
- ° Isolation from terrestrial environment provides vibration noise isolation, as well as other isolation important to utilization of biorhythms.
- ° There are, as yet, no identified uses for very hard vacuum alone. However, that property is a very necessary supporting condition for processes utilizing other properties (i.e., containerless processing in zero-g.)
- ° Medical (therapeutic, diagnostic, public health), electronic, power, and other commercial uses promise at least a one billion dollar per year industry, as well as military and environmental benefits.

Mr. Bloom stated that some companies were as concerned with the business/legal problems that could develop as a result of their involvement with space to produce commercial products as with the technical feasibility of concepts offered. Some questions typically asked by users:

- ° How will NASA protect my proprietary data or equipment?
- ° What rights will NASA grant for data, products, or patents?
- ° Who pays for space experiments or tests or equipment to develop the product, process, or service?
- ° What role does NASA (or G.E.) play in programs following B.U.S.?
- ° What is the probability that there will be a Space Shuttle or (facility)?
- ° What will it cost to run experiments or use a space facility?

Phase II of the B.U.S. study was aimed at advancing from the Phase I identification of potential products, processes, and services to the definition of technical and planning data required for eventual implementation of typical identified ideas.

Again a close interaction between the aerospace B.U.S. Team and the non-aerospace users produced significant results.

Conclusions drawn from the Phase II study were:

- User response derived 30 major alternative approaches for producing for typical products.
- Projecting technology for 1980 and beyond is shaky.
- Non-aerospace users need education and exposure to low cost experiment and test methods.
- Ten year R&D program is "comfortable."
- Users seeking earliest indicators of process feasibility.
- Program decision data (user and NASA) is incomplete.
- Legal and financial issues are major nodes in decision flows.

The intent of the Phase III study was to provide measures of business potential for typical space-produced products using the formation of thorough business plans. Mainly, it was a study using cost, value analysis for production and potential profitability of four products:

- Tungsten X-ray targets
- High specificity separation of isoenzymes
- Surface acoustic wave electronic components
- Transparent oxides

The Phase III Study Business Plan followed the sequences:

- Market Survey
- Development Cost
- Methodology and Procedures for Future Products
- Comparison

The R&D cost and profit analysis shows:

- ° Tungsten - \$9 million, break even point - 7 years
- ° Isoenzymes - \$4 million break even point - 9 years
- ° Transparent oxides - \$18 million, break even point - 9 years
- ° S.A.W. (surface acoustic wave devices) - \$15 million, break even point - 13 years

Cost of a good R&D effort is the major problem.

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COMMERCIAL MANUFACTURING IN SPACE - A FEASIBILITY STUDY

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Mr. Bill Marx gave a talk entitled, "Feasibility Study of Commercial Space Manufacturing," with a presentation focused on the Silicon Ribbon Study. The study period was from 1974 to 1976 and the data was, therefore, relatively current.

The presentation began with the discussion of the evolution of experiments in a micro-g environment during the 1960s. It was recognized early on that the initial phases would be government financed with "industry participation." The ground rules assumed for this study were as follows:

- A commercial plant would be launched by 1985.
- The system should be essentially automated with manual overrides because of the high cost of maintaining a man in space.
- A five-year life.
- Constant 1976 dollars.
- All R&D would be funded by the government up through pilot projects.
- The financial analysis in the study is consistent with current commercial practice.

The market analysis concentrated on Large-Scale Integrated Circuits (LSI) applications and solar cell evaluation was not excluded in the market study. Various methods for ribbon shaping were examined and these are itemized below:

- Mechanical shaping developed problems because all known materials are incompatible with molten silicon and cooled dies cause polycrystalline ribbon.
- Acoustic forces require an atmosphere to transfer sound waves (5 Torr minimum).
- Radio frequency forces appeared to be the most promising.

The third method was selected and Motorola has already demonstrated that it could be done by this method. Power requirements were a function

of the ribbon width and thickness. A solar furnace would be used which has a requirement of about 1.0 kWh of power. The manufacturing facility would weigh about 10,000 lbs. (fully loaded) and would comprise a physical size of about 11 x 10 x 10-1/2 feet. Facility power would be about 4.5 kWh average.

Since it was assumed that each facility could produce about one percent of the market and ten percent of the market could be captured, ten units would be required in space. Each Shuttle could carry five units. Service would be required every four to eight months to recover the ribbon.

Different economic schemes were investigated along with risk assessment and various ROI factors were calculated. The risk factors were:

- o technical risk
- o legal risk
- o market risk

All these factors were discussed from "today" through completion of "pilot plant demonstration." All economic calculations were adjusted for implementation risk and it was concluded that the only way a profitable venture would take place would be for the government to underwrite all R&D costs up to and including pilot plant feasibility.

It was determined that space commercialization requires the aerospace and commercial industries to be partners with the government with their roles interdependent.

The study conclusions were as follows:

- o Space manufacturing appears feasible with no insurmountable problems.
- o Silicon ribbon typifies good product candidate with a large, expanding market and a high value product.
- o Today, risk blocks private venture capital.
- o Government actions for space commercialization should encourage industrial participation through sponsorship.
- o Initial demonstration provides the catalyst for other private space manufacturing ventures.

SPACE PROCESSING - IMPORTANCE TO INDUSTRY

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Dr. Steg's comments focused on:

- Space processing from an industrial point-of-view
- Space processing from a general perspective and some associated problems
- Science and Society (the hidden agenda -- where is science going?)

Dr. Steg's remarks on space processing from an industrial point of view are contained in his paper, "Investment in Space -- When and How." The focus of the paper is to examine investment in R&D by business, and what would be necessary to get firms to invest in space processing. He believed space processing will come, but that the restraints on business participation are severe. Some problems identified were:

- The market for space produced products and the process of technology transfer are not well understood.
- Space processing is very sophisticated.
- "Place-of-business" concept is not well suited to space processing facilities.

Examination of some models of business/government cooperation so as to understand the role of the Federal Government in materials processing in space is needed. Sample model includes:

- "The Jet Engine Model"
- "The Nuclear Model"
- "The COMSAT Model"

Also mentioned was the upcoming NAE Space Application Board Study of the business aspects of space processing.

Dr. Steg then moved to the "hidden" agenda, the role of technology in the future, an issue in which space processing is only a subset. He placed himself in the position of a "cornucopian," one who views the future of technology favorably, as opposed to a "catastrophist," who views the future influence of technology as negative.

A question and answer period followed:

Q. What are the social impacts of space processing?

A. In science, other areas of space appear more important; e.g., astronomy; a space telescope will revolutionize that discipline. In terms of practical applications to society; e.g., new biological separation processes, new electronic materials, etc., the social impact is difficult to predict at the present time.

Q. What are the shortfalls to achieving space industrialization?

A. The really creative people are not involved and generally disdain space. There is a need to get creative people, who can span disciplines, involved.

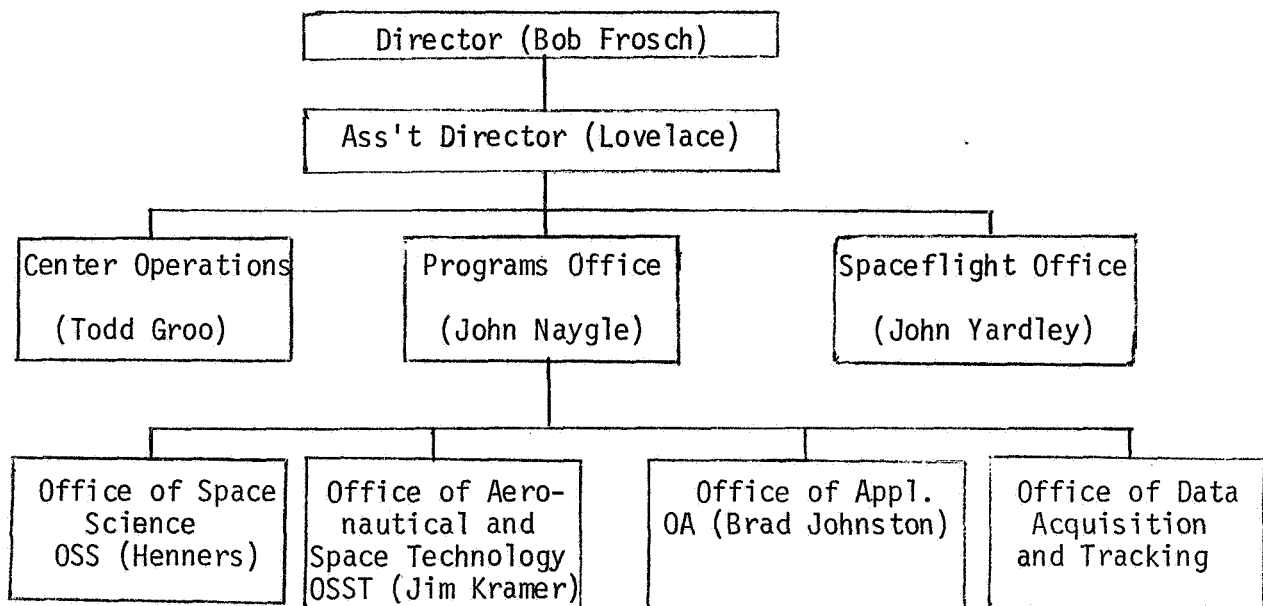
Q. What is the progress of non-U. S. R&D in space processing?

A. The U. S. is the undisputed leader; in Germany there is a strong effort similar to the U. S.; the U.S.S.R. believes that there may be a "pot-of-gold" in commercial applications of space; in Japan there is interest and some preliminary studies.

MATERIALS PROCESSING IN SPACE

John Carruthers
 Director, Materials Processing in Space
 NASA Headquarters
 Washington, D.C.

NASA Organization. Dr. Carruthers has a background in crystal growth at Bell Labs, where he was involved in a floating zone crystal growth experiment on Skylab. He has recently moved to the NASA office of Applications as Director of the Materials Processing in Space Division. His presentation began with an organization chart of NASA Headquarters:



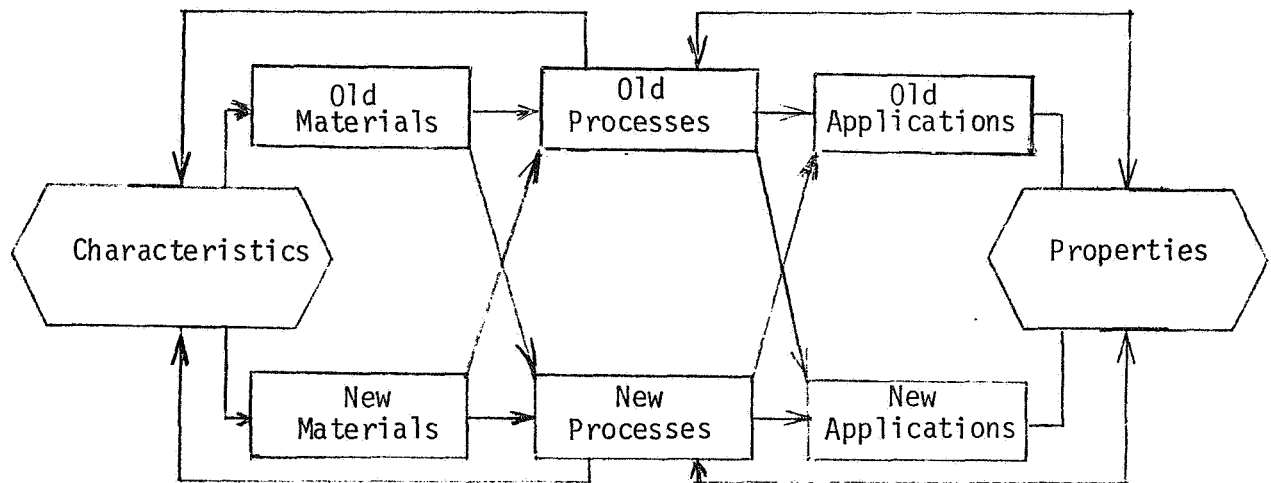
The OA has a number of divisions including:

- Satellite Communication
- Earth Resources
- Material Processing in Space
- Meteorology
- Special Projects

There is now renewed NASA interest in satellites for those service programs that are not profitable to single industries; for example, the tracking of maritime shipping for search and rescue, monitoring the U.S. 200 mile coastal limit, and crop surveying with LANDSAT. There are some political problems, such as the displacement of hundreds of wheat inspectors, and there is also a data reduction problem of getting pertinent information for the various users.

Material Processing in Space Organizations. NASA funding for material processing in space is complicated by the new zero-based budgeting and the long lifetime of most processing programs, but the expected funding for material processing is: FY 76, \$5 M; FY 77, \$9.3 M; FY 78, \$15.5 M; and FY 79, hopefully around \$26 M.

The basic philosophy and approach for doing material processing in space was discussed and summarized as a flow chart with feedback:



The feedback loops represent iterative attempts to continually improve materials and final products, and the forward flow illustrates the way old and new processes interact. This interaction was illustrated by two product developments at Bell Labs. The first transistor was obtained by applying the new process of zone refining to the old material of germanium to finally get the required purity. A second example is the development of a new crystal growing technique to produce the very high quality ruby crystals necessary for the Telstar solid-state maser receivers. Based on such past experience, the development of material processing in space will focus initially on new processes.

Material Processing Considerations. There are several unique advantages of using space for processing. First, the microgravity allows containerless processing using either electromagnetic, acoustic, or electrostatic positioning. Also, such effects as density-driven convection, Stokes settling, hydrostatic pressure gradients, and the self-deformation of solids can be eliminated or greatly reduced. Secondly, the ultra-high vacuum and pumping speed obtainable in earth orbit with the molecular shield concept should allow work to be done at around 10^{-15} atm. as opposed to around 10^{-12} atm. on Earth. It should also lead to a new type of monoenergetic oxygen beam. A third advantage is unlimited solar power, which is particularly important, since most material processing requires high power. A solar power module for the Shuttle is now under development (phase B) by the Office of Space Flight and will provide 25 kW, of which 7 kW will be available for material processing. Although silicon solar cells are excellent for low power levels in space, they are not now economically feasible for large power plants. In fact, it takes more energy to manufacture a cell

than the cell will produce over the nominal seven-year lifetime! A fourth advantage of space is the essentially unlimited volume for waste disposal, although the more desirable Earth orbits are now getting somewhat crowded.

The proposed approach by NASA to material processing in space is to identify a "shopping list" of scientific investigation areas which could lead to promising products, then select a "bullets list" of prototype products to manufacture. These products would then be supported by additional scientific research. Initial products should be: (1) unique to space manufacturing, (2) of demonstrated interest, and (3) relatively certain to work. Three such products were presented and discussed. First, glass microballoon, 1 mm in diameter, might be produced with high yields for use in laser fusion research, where there is a large potential market. Second, the industrial process for making polystyrene latex spheres might be "rediscovered" in the absence of gravity. There is a large potential market for these latex spheres. The third is infrared detectors, which are very important for satellite surveillance of the earth. If impurities could be reduced by space manufacturing, then there would be a very large military market.

There are several aids to use to select these "bullets". Marketing surveys have been run, but with poor results due to the high uncertainty of the products and general distrust of government by industry. There now exists an advisory group, the University Space Research Assn. (USRA), which advises NASA on basic science. A similar group would be desirable for products, but does not now exist. However, the National Academy of Sciences has commissioned a large study, the second phase of which will consider products. The NASA-industry interface problem is difficult, but it is felt that NASA must then decide if it is beneficial to go into production, and, if so, how the legal factors are to be resolved.

Responses to questions included the following items:

- Congress tends to be quite friendly toward material processing in space, and is particularly interested in interfacing with industry. Key senators are Stevenson and Fuqua. The GAO holds NASA to a close accounting of all funds and programs. However, the president, through OMB, tends to restrain NASA via the budget, hence NASA is being pulled in opposite directions.
- Often NASA interest in a process can cause improvement in earth-bound processing due to wider exposure, e.g., electrophoresis.
- There have been additional biological "bullets" proposed. One is the attempt to culture antibiotics in floating drops of liquid, which could reduce the processing time from 8 years to around 18 months. Another possibility is improved identification of red blood cells by eliminating their sinking when placed under a microscope.

- When money begins to come in from industry, it is possible that the NASA budget may be correspondingly reduced, but this would probably have a positive effect on funding for new programs.
- The NASA charter prohibits getting into the defense business, but there is some military overlap in space manufacturing and jointly-beneficial programs are a definite possibility. There are no DoD representatives in the Materials Processing Division of NASA, but a study to identify potential military users will be made this year.

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PROJECT EXPLORER

Konrad Dannenberg
Associate Professor
University of Tennessee Space Institute
Tullahoma, TN

Professor Dannenberg began his talk with a brief history of the U. S. space program, starting with the launch of the Explorer satellite in January 1958. He traced the development of rocket engines from the early Viking missile to the Saturn V.

He noted that the space program does not have the wholehearted support of the public and that it is necessary to sell the space program. An important segment of the public who should become involved in the space program is the youth. The Explorer Project will attempt to get students involved in the Shuttle Program.

The Explorer Project will invite high school students to propose experiments suitable for space flight, and will encourage universities to participate by evaluation, selection, and scientific support of the students and their experiments. Also, the universities are asked to provide some financial assistance to the student for their academic careers. The program will allow student participation in space activities on a broad scale and will enlist university support as necessary. The program is sponsored by the Alabama Space and Rocket Center (ASRC), NASA and the Marshall Space Flight Center (NASA/MSFC), and the Alabama section of the American Institute of Aeronautics and Astronautics (AL/AIAA).

The first student projects will fly on the Shuttle in 1980. There will be additional flights involving student projects each year thereafter.

The potential experimental categories and the anticipated scientific and engineering areas open for research were discussed. A summary of this discussion along with complete information on dates, weight and size of experiments, cost and power limitations is available in the document "Project Explorer," which is available from Professor Dannenberg. He concluded his remarks by stating that the Explorer Project is a pilot program and is expected to expand to include many universities and students.

FUTURE PROJECTS IN SPACE

Jesco von Puttkamer
Advanced Programs
Office of Space Flight
NASA Headquarters
Washington, D.C.

Long range planning involves intensive interaction with outside groups. There are two types of planning or forecasting:

- Extrapolation is a simple projection from current trends (Mr. von Puttkamer prefers an S-shaped as opposed to linear extrapolation).
- Normative planning is a jump into the future; postulate a future as the norm and then work backwards.

The two together are termed Push-Pull (extrapolative-normative, respectively) planning. The idea is to see what steps in the near future may lead to postulated far-futures so as not to foreclose potential far-future options.

The programs performed by NASA in the past have given experience in Operations, Systems and Management. The idea is to build on these proven experiences to capitalize on our investments.

The rationale for Space Industrialization was broken down into six areas:

- Political
- Social
- Economical
- Technical
- Environmental
- National Security

Reference was made to Space Industrialization Studies by Rockwell and Science Applications (SAI).

Space Industrialization was broken into four categories:

- Information

- Energy
- Materials
- People

Each area was generally broken down into an activity (information) and then to an industry (communications) and into a product/service (locator).

A question and answer period followed. Many of the replies are answers to unstated questions.

Military applications are assumed to be a part of space-related activities. Commercial applications seem always to require justification.

Studies by Rockwell, Science Applications and Aerospace Co., identified several space industrialization opportunities.

Some examples were given for each of the space industrialization categories (information, energy, materials and people).

Two Shuttle flights are required for a two-way wrist radio communications satellite.

A timetable was displayed for development of a Public Services Platform Satellite. (An assumption made is that the services would pay their own way.) The station might be operated by COMSAT, by a TVA-type organization, by NASA, or maybe by a commercial outfit.

The Evolution of Space Industrialization was identified to have the following steps:

- Unique materials which can only be formed or processed in space
- Better: those which are better done in space
- Cheaper: those which are cheaper done in space
- Relief of Biosphere: those which are energy- or pollution-intensive, or hazardous
- Products to achieve self-sufficiency in space

Examples of energy applications were given: Solar Power Station, Lunetta, Soletta, and nuclear waste disposal. The Solar Power Station is expected to be operational anywhere from the year 2010 to 2060. He feels that there are many companies that will pay for satellite development.

A chart was shown giving the expected evolution of the Space Transportation System. The Space Construction Base is expected in the 1985 - 1987 time period. The loiter time of the Shuttle with a 25 kWh power module is 90 days, limited by boil-off losses of the fuel cell cryogenics. An Orbital Transfer Vehicle will be required in 1988 to maintain the desired timetable.

The Office of Space Flight five-year plan shows the following milestones:

- 250 kWh Power Module (10C 1984)
- Advanced Communication System (10C 1985)
- SPS Test Vehicle (10C 1986)
- Material Processing Module (10C 1986)

The 560 flights now planned do not include any of these four milestones. Although some of these milestone activities could be done with the present Shuttles, more probably have to be built.

Three orbiters are planned for NASA and two for DoD.

NASA may pay for the two Shuttles flying out of Vandenberg. The upper stage (IUS and SSUS) are being built by the Air Force. The Air Force will modify their orbiters, and will continue to fly TITAN IIIC's during the time that the Shuttle is proving itself.

Beam building machines will be used to fabricate large structures in space.

The guiding principles for Support Functions were identified as follows:

- Fabrication
- Assembly
- Test
- Service
- Modify

Manned and automated (unmanned) operations are complementary.

Typical Advanced Development Projects were identified as:

- Beam Builder

- Tethered Satellites
- Space Spider
- Manned Work Station
- Satellite retrieval, maintenance and repair

Expected accomplishments by the Office of Space Flight by 1987 are:

- 25 kWh Power Module
- 250 kWh Power Module
- Demonstration of the feasibility of materials processing
- A LEO advanced communications system
- Development and flight of an ion propulsion stage (SEPS)
- Development and flight of a Manned Orbital Transfer Vehicle (MOTV)
- Development and orbital testing of large structures designed for solar energy collection and transfer

The 10-year budgetary outlook for NASA within the Office of Space Flight indicated that money will be freed as development of the Shuttle proceeds. The funds thus freed could be used for these purposes.

Although some people think 60 flights per year are unreasonable, Mr. von Puttkamer is confident that we can accomplish this many flights per year.

The employment at KSC is expected to remain steady.

By the 1990's we will have to revisit the Moon. NASA is considering lunar mining. A lunar station looks much better if oxygen is mined on the Moon rather than imported from Earth.

In-house studies were undertaken to look at international cooperation. A new agreement between the U. S. and Russia has been signed to set up the following three committees:

- Shuttle to visit a Salyut or similar early project
- To study cooperation in Space Science
- International Space Station

THE SYSTEMS APPROACH METHODOLOGY - PART II

Reginald I. Vachon
Mechanical Engineering Department
Auburn University
Auburn, AL 36830

Dr. Vachon evaluated the results of the First Interim Report and made several suggestions. If you manufacture something in space, what will be the reaction from:

- o Congress
- o People
- o Washington
- o Entrepreneurs
- o What are we going to do with the Shuttle?

NASA will expect you to provide direction with your study. NASA is looking for guidelines and looking forward to final report. Ask yourself, is the Shuttle premature?

Call people, use the FTS system as often as practicable, get involved, call your Congressman, ask questions. Get information from top people in politics, science, materials, chemical, space engineering, business, commerce, medicine and any others that may contribute some information.

Establish upper and lower boundaries to describe facilities. How do Europeans feel about processing in space? Do they see commercialization possibilities in the future or do they see only R&D now? How does something pay for itself? What is the national picture as to political, economical and people's perception or receptivity to R&D?

What will happen if we run out of the fruits of R&D? Key into new product packages, new schemes, Department of Commerce, productivity, labor problems, etc.

Who gains on the investment? Who loses if ROI isn't there? What are the local aspects, patent problems? What should you do to get ready for commercialization?

ADVANCED TRANSPORTATION SYSTEMS

Philip K. Chapman
Avco-Everett Research Laboratory
2385 Revere Beach Parkway
Everett, MA 02149

Dr. Chapman set the vision for future goals in space by stating his views on pertinent topics, e.g.:

- Space colonization is inevitable
- Interstellar travel is possible
- Long-term future of man on Earth is bleak without the support of space

Without activities directed toward the development of space, he feels the prophets of gloom may be correct and there may be a long dark age ahead. He also stated that to be effective, the space efforts must recognize the economic, industrial, and congressional constraints.

Dr. Chapman had reviewed the group interim report and cautioned the group against making assumptions on cost, time, and technology that were too conservative. He warned against using the Space Shuttle and the NASA budget as independent variables in the study.

In discussing space transportation systems, he pointed out that small improvements in system design can make significant difference in payload capacity. A study is needed on the advantages of a single stage HLLV.

Advanced Transportation Systems Discussed:

Nuclear Rockets have a fundamental technical problem and the program is presently inactive.

Laser Propulsion has the power source separated from the rocket. A laser beam from the ground is directed toward the rocket. The energy is absorbed in a gas which is accelerated from the back of the rocket. A laboratory model has been constructed.

- Problems: (a) Can a 1 g-watt laser be built?
(b) Can a 1000 Km laser beam be directed through the atmosphere?

It is easier to go to G.E.O. than to L.E.O. with this system.

Single Port Throatless Detonation Wave Rocket uses a laser engine which is low power pulsed followed by high power pulse and which appears possible on large scale.

Dr. Chapman stated that not to do laser propulsion is a failure of will rather than a failure of technology. He feels it will be available 10 years after people stop laughing.

TECHNOLOGY ASSESSMENT

Christopher T. Hill
Materials Program
U.S. Congress
Washington, D.C. 20510

Dr. Hill defined technology assessment (TA) as:

A class of policy studies which seeks to examine the impacts on society that may occur if/when technology is introduced, extended, or modified with emphasis on those impacts which are unintended, unanticipated or delayed.

Some other definitions:

Policy is an agreed upon strategy or course of action.
Impacts are of an environmental, socio-economic, labor/employment, resources, community values, and related natures.
Technology can be thought of as the process of applying science/knowledge (software & hardware), or in other, more broad, ways.

TA is different from the systems approach and is more than operations research or technology forecasting.

TA main characteristics:

- ° Synthetic (creative)
- ° Analytic
- ° Iterative (continuously improving).

Some other TA characteristics:

- ° Full participation by parties at interest
- ° Anticipatory futures research
- ° All-inclusive, objective
- ° Interdisciplinary-vocabulary is critical.

TA institutions include the National Science Foundation (NSF) program under G. Patrick Johnson. Other institutions involved are: Office of TA and Forecast (OTAF), and International Society for TA (ISTA). Studies were done by National Academies of Science and Engineering and by National Academy of Public Administration (NAS, NAE, NAPA) on who should do technology assessment.

In October 1972, TA Act established Congressional Office of TA (OTA). OTA is ruled by TA Board consisting of six (6) Representatives and 6 Senators. Senator Edward M. Kennedy (D-Mass.) is Chairperson. There are four (4) other Congressional Committees involved in OTA management:

- ° House-Science and Technology Committee
- ° House-Subcommittee on Legislative Appropriations

- ° Senate-Subcommittee on Legislative Appropriations
- ° Senate-Commerce, Science & Transportation Committee

The OTA Advisory Committee (TAAC) consists of ten (10) members. Jerome Wiesner (MIT) is Chairperson.

There is an OTA Director (vacant), Deputy Director (Dan DeSimone); Professional Staff (150 members).

Four purposes and functions of Congress which OTA assists:

- ° Policy Development
- ° Legislation
- ° Oversight
- ° Budget and Appropriations

Some OTA functions:

- ° Technology evaluation and assessment
- ° Policy studies
- ° Analysis of executive plans and proposals.

Distinction is made between problems and issues; Congress' main concern is on issues and conflicts.

TA Approach:

- ° Description of technology and major alternatives in future context--forecast of technology state of art and state of society.
- ° Identification and analysis of possible impacts.
- ° Identification of parties of interest.
- ° Identification of relevant policy options.
- ° Evaluation of alternatives and options.
- ° Communication of results to decision makers.

Do technology assessment four (4) times using 1%, 15%, 70%, and 14% of time, effort and resources.

Policy-making options:

- ° Information - fund R&D and training; publish; patent
- ° Incentives - subsidies, taxes, grants
- ° Direct control - banning; licensing technology and individuals; regulatory standards
- ° Action - construct facilities; provide services

Policy research is not science (application of scientific method to understand world).

The TA Method includes brainstorming, expert panels, morphological analysis. Use is made of linear matrix algebra, modelling and simulation, systems dynamics, event-sequence tree, for impact analysis.

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NASA PLANNING

George Bucher
Deputy Associate Director for Science
Marshall Space Flight Center, AL 35812

In 1975, NASA recognized the need to establish long range goals. A study group was set up and produced a report, "Outlook for Space". This group tried to indicate those activities that appeared to be most desirable and most feasible for NASA to pursue. The report contains recommendations, but is not a formal NASA planning document. The "shopping list" of possible endeavors permitted different elements of NASA to consider activities in their realms of responsibility, and to formulate sets of desired activities for forthcoming years. Restrictions upon the NASA budget makes it difficult to include the desired activities of all NASA elements in a consolidated agency plan. The budgetary plan for FY78 is fairly firm, and one is now being formulated for FY79; beyond that, plans are less firm.

NASA 5-year plans are based upon forecasts which estimate dollar trends for various projects. Historically, some 5-year forecasts have been accurate and some inaccurate. For the past five years, the NASA budget has been essentially level.

Materials processing in space occupies a relatively small but viable niche in NASA.

The Shuttle is basically a transportation system with a crew. Manned and unmanned experiments will be carried, and will be given equal emphasis.

In Dr. Bucher's opinion, the reasons for the drop in NASA funding after completion of the Apollo missions were:

- o Apollo objectives were attained, with a consequent decrease in glamour of projects that followed
- o The administration was placing emphasis upon human welfare
- o There was a general disenchantment with science and technology
- o There was an absence of major Agency-wide future objectives in NASA (like Apollo)

NASA is striving to alleviate this in the future by concentrating upon activities that are acceptable to Congress and the public. Increasing emphasis is being placed upon application projects.

L-66

Putting a man on the Moon was primarily a technological problem. When people are involved, the problem expands to include socio-political aspects. For example, union restrictions and local building codes can hamper the introduction of space technology into residential construction.

ENVIRONMENTAL CONCERNS AND SPACE

Earl Bailey
Associate Professor, University of Alabama and
Vice President, Sierra Club
Tuscaloosa, AL 35401

Professor Bailey conducted a general discussion of the activities of the Sierra Club, Southeast District, related to energy, forestry, farming, pesticides, strip mining and conservation.

The Sierra Club was characterized as a lobby group serving the interests of the membership in preventing environmental pollution, preserving wilderness areas, and protecting wildlife.

Policy papers on various subjects are available from Sierra Club offices, and include such areas as soil erosion, energy, nuclear power, pesticides, etc. The improvement of efficiency in air transport engines is of current, high priority interest. A Sierra Club policy on any given subject takes years to develop, and is generally an outgrowth of numerous debates, public hearings, and conferences conducted over several years.

A summary of a question and answer period follows:

What is the Sierra Club's attitude toward extremely large power plants such as the SPS?

The Sierra Club has no objection to such plants solely because of size. The key consideration is efficiency, which is now about 10% to end use. That efficiency must be improved if waste heat problems are to be reduced.

What is the Sierra Club's attitude toward Satellite Solar Power Stations?

No established policy.

Is there any chance of utilizing space as a means of reducing pollution?

One possible area is in radioactive waste disposal. But, much caution should be exercised regarding ionospheric interruptions caused by rockets or orbiting satellites.

At what point does Sierra Club become involved in a particular project?

There is no formal review procedure. When a project is so large that an environmental impact statement is required, then that statement becomes an invaluable tool for alerting or informing the public (including the various environmental groups) as to the issues involved. This, in turn, may lead to involvement by some of those groups.

Previous comments seemed to indicate that Sierra Club advocates Federal regulations concerning environmental protection. Why not incentives rather than regulations?

The Sierra Club, in general, supports incentives rather than regulations, but recognizes that the current trend is toward regulations.

How would the Sierra Club choose between a low technology solution and a high technology solution to a particular problem, where either solution would cause pollution?

The Sierra Club places no preference toward either low or high technology. Each case would be judged on its own features.

What is the Sierra Club's attitude toward President Carter and his position on environment?

The Sierra Club is very pleased at having a strong conversationalist as President, the first since Theodore Roosevelt. The Sierra Club is now in a strong position in the Administration, and, in fact, is able to be of some influence in the Administration due to Carter's appointing several Sierra Club members to key positions. The Sierra Club strongly supports use of coal as an energy source, but admits that the conversion to coal probably cannot be made in an environmentally accepted manner in the time frame in which the conversion is currently being planned.

At what point should NASA initiate the Environmental Impact Statement on projects in space?

The key to planning is to allow enough lead time to resolve environmental issues and to be thoroughly prepared to discuss those issues. The time frame cannot yet be predicted for such studies.

How are standards of acceptability for a particular project set by the Sierra Club?

The standards are set through public debate in public hearings, sometimes resulting in federal laws or regulations. Standards are sometimes simply set by a consensus following detailed discussions. Final standards are not set by environmental groups.

Future activities of the Sierra Club must be better founded and technically proven. "Scare" propaganda and delay and harrassment tactics are no longer acceptable. In the past, many people have used the form offered by environmental groups to promote other interests (anti-war, zero population, etc.). This abuse has caused much repercussion and bad P.R. Pollution related to aerospace programs has been treated on a hit-or-miss basis by Sierra Club in the past. It is likely that a committee will be formed within the next year to deal with such problem areas.

THE U. S. SENATE AND PROCESSING IN SPACE

Allan Hoffman
Staff Scientist
Subcommittee on Science, Technology and Space/Committee on
Commerce, Science and Transportation
U. S. Senate
Washington, D.C. 20510

Dr. Hoffman opened with a statement about his committee. In January 1977, there was a reorganization of the Senate committee structure and personnel. The responsibilities of the Aeronautics and Space Committee were transferred to the Committee on Commerce, Science and Transportation. The staff members of the Subcommittee who are likely to be concerned with NASA programs are:

Jim Gehrig - former Aeronautics and Space Committee staffer
Craig Vorhees - former Aeronautics and Space Committee staffer
John Stewart - political scientist
Allan Hoffman - physicist

The Subcommittee on Science, Technology and Space exercises the full committee's oversight authority over NASA programs, but has no appropriation authority. As a result of the Senate reorganization, there are no longer ex-officio members of the Space Committee on the NASA appropriation subcommittee. It will be the task of the space community to educate Senate members as to the value of the NASA programs.

The question and answer period brought out the following points:

- SPS: There is skepticism about the project by Frank Press (the President's Science Advisor), James Schlesinger (the Head of the Department of Energy), and NASA Administrator Robert Frosch, particularly with respect to timing.
- There are no specific plans at this time by the Subcommittee on Science, Technology and Space to use the services of the Office of Technology Assessment.
- Patent Policy: May be an important factor in the innovation cycle; will be viewed carefully by the President's Science Advisor and by the Assistant Secretary for Science and Technology of the Department of Commerce.
- NASA: A maturing organization which now will be concerned with important but more mundane matters and fewer spectacles.

- NASA Budget:
 - Real NASA spending has been reduced by asking only for a constant budget without asking for increases to compensate for inflation.
 - Zero-base budgeting should not have a major impact on NASA programs.
 - If NASA is overly conservative in its budget requests because of limits imposed by OMB, it would not be inappropriate for the committee to recommend a higher expenditure level.
 - A potential obstacle for NASA, as well as for R&D expenditures throughout the federal budget, is President Carter's decision to have a balanced budget by 1981.
- Space Industrialization: Careful evolutionary progress is needed. This should include the development of large space structures, the study of human problems in space, and careful consideration of international and private sector questions.
- Miscellaneous:
 - NASA-DoD relations: DoD pushed for a five-orbiter fleet. A Soviet space station will bring pressures to orbit a U. S. space station.
 - Congress generally considers NASA programs well managed.
 - There is no urgency for a second-generation U. S. supersonic transport; need experience with Shuttle first.
 - There is little chance for a private space transportation system at this time because of costs and regulations.
 - NASA should continue a strong space science program.

THE U. S. ARMY'S INTEREST IN MATERIALS PROCESSING IN SPACE

Shelba Brown and
Jim Davidson
Material and Manufacturing Technology Section
U. S. Army
Redstone Arsenal, AL

Ms. Brown and Mr. Davidson responded to questions by the faculty fellows as follows:

- What are the interfaces between the Army and NASA?
 - There are no formal technology transfer channels between the Army and NASA.
 - Personal interaction occurs frequently.
 - The Army usually transfers its technology through publications (NASA is outstanding in getting information out quickly).
- There are no intentions to use Space Shuttle.
- There is a possible duplication of research between the two groups.
- The Army has problems with missile radome materials.
- The Army needs thousands of tons of material and thousands of individual items where NASA needs small numbers of items.
- It takes time to get the cost of new NASA developments down to where the Army can afford them.
- The Army will help with equipment problems when approached.
- Most data is not classified except that which is normally associated with mission, numbers, and such items as sophisticated guidance systems.
- The Army is interested in laser optics.
- The Army is interested in metallurgical advancements.
- The Army is interested in crystallographic developments for guidance equipment.